EFFECT OF SOYBEAN CROP PHENOLOGY
ON DEVELOPMENT, LEAF CONSUMPTION, AND OVIPOSITION
OF *Anticarsia gemmatalis* HUBNER

BY

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To my wife, Rosa Maria, and son, Gustavo,
whose love, understanding, and personal sacrifice
ultimately made this work a reality

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TABLE OF CONTENTS

ACKNOWLEDGEMENTS.. iii

LIST OF TABLES.. vii

LIST OF FIGURES... x

ABSTRACT.. xii

INTRODUCTION.. 1

LITERATURE REVIEW... 6

- Life History.. 6
- Distribution.. 10
- Seasonal Occurrence... 11
- Host Plants... 13
- Natural Enemies... 16
  - Parasitoids... 16
  - Predators... 17
  - Pathogens... 17
- Soybean Response to Defoliation and Economic Thresholds for *Anticarsia gemmatalis*.................................. 21
- Temperature Studies on Insect Biology............................... 23
- Insect Feeding Studies and Effect of Nutrition on Insect Biology.. 29
- Soybean: Generalities and Nutrient Distribution According to Plant Phenology...................................... 39

METHODS AND MATERIALS... 43

- Effect of Soybean Phenology on *A. gemmatalis* Consumption and Biology.. 43

General.. 43

Plant Phenology and Consumption........................ 44

Plant Phenology and Development........................ 47

Plant Phenology and Fecundity........................... 47

Effect of Temperature on *A. gemmatalis* Fecundity............ 48

General.. 48

Constant Temperature Regimes........................... 52

Variable Temperature Regime............................. 52

Field Study.. 52

RESULTS AND DISCUSSION...................................... 54

Effect of Soybean Phenological Stage on Consumption and Development of *A. gemmatalis*............................ 54

Effect of Soybean Phenological Stage on Fecundity, Egg Hatch, and Longevity of Adult *A. gemmatalis*.............. 67

Effect of Temperature on Oviposition, Egg Hatch, and Longevity of *A. gemmatalis*.................................. 82

CONCLUSIONS... 102

APPENDIX.. 107

LITERATURE CITED... 128

BIOGRAPHICAL SKETCH.. 139

LIST OF TABLES

Table / Page

1 *Anticarsia gemmatalis* host plants...................... 14

2 Reported parasitoids of *Anticarsia gemmatalis*........... 18

3 Insect predators of *Anticarsia gemmatalis*............... 19

4 Stages of soybean development (Fehr and Caviness 1977) during laboratory feeding studies with *Anticarsia gemmatalis*.. 43

5 Number of leaflets, initial larvae/leaflet, and control leaflets, used in feeding studies with *A. gemmatalis*, according to plant stage and larval instar.............. 46

6 Mean fresh and dry weight consumed by fourth and fifth instar *A. gemmatalis* larvae fed excised leaves of successive soybean phenological stages. Temperature = 26.7° ± 1°C; photoperiod = 14L:10D; humidity >80%.. 55

7 Hatching to pupa, pupa to adult, hatching to adult mean developmental times, pupal weight, and sex ratio for *A. gemmatalis* larvae fed excised leaves of successive soybean phenological stages. Temperature = 26.7° ± 1°C; photoperiod = 14L:10D; humidity >80%.. 64

8 Mean fecundity, egg hatch, longevity and net reproductive rate (Ro) for *A. gemmatalis* females resulted from larvae fed excised leaves of successive soybean phenological stages. Temperature = 26.7° ± 1°C; photoperiod = 14L:10D; humidity >80%.................... 68

9 Mean fecundity, egg hatch, longevity, and net reproductive rate (Ro) for *A. gemmatalis* females reared from eggs at different temperature regimes. Photoperiod = 14L:10D; humidity >80% except for field experiment... 83

10 Average daily fresh weight consumption (grams ± SE) for *A. gemmatalis* larvae fed excised leaves from successive soybean phenological stages. Temperature = 26.7°C; photoperiod = 14L:10D; humidity >80%............ 108

11 Total fecundity per mated female resulting from larvae fed excised leaves from successive soybean phenological stages under laboratory conditions. Temperature = 26.7°C; photoperiod = 14L:10D; humidity >80%.. 109

12 Average daily fecundity (± SE) of *A. gemmatalis* females resulted from larvae fed excised leaves from successive soybean phenological stages. Temperature = 26.7° ± 1°C; photoperiod = 14L:10D; humidity >80%.. 110

13 Fertility table for *A. gemmatalis* females resulted from larvae fed early vegetative stage soybean leaves. Temperature = 26.7° ± 1°C; photoperiod = 14L:10D; humidity >80%.. 111

14 Fertility table for *A. gemmatalis* females resulted from larvae fed late vegetative soybean leaves. Temperature = 26.7 ± 1°C; photoperiod = 14L:10D; humidity >80%...... 112

15 Fertility table for *A. gemmatalis* females resulted from larvae fed flowering stage soybean leaves. Temperature = 26.7° ± 1°C; photoperiod = 14L:10D; humidity >80%..... 113

16 Fertility table for *A. gemmatalis* females resulted from larvae fed pod set - pod fill stage soybean leaves. Temperature = 26.7° ± 1°C; photoperiod = 14L:10D; humidity >80%.. 114

17 Fertility table for *A. gemmatalis* females resulted from larvae fed senescent stage soybean leaves. Temperature = 26.7° ± 1°C; photoperiod = 14L:10D; humidity >80%..... 115

18 Total fecundity per individual female reared from eggs at different temperature regimes. Photoperiod = 14L:10D; humidity >80% except for field experiment...... 116

19 Average daily fecundity (± SE) of *A. gemmatalis* females reared from eggs at different temperature regimes.. 117

20 Fertility table for *A. gemmatalis* females reared from eggs at a constant temperature of 21.1° ± 1°C; photoperiod = 14L:10D; humidity >80%.................... 119

21 Fertility table for *A. gemmatalis* females reared from eggs at a constant temperature of 23.9° ± 1°C; photoperiod = 14L:10D; humidity >80%.................... 120

22 Fertility table for *A. gemmatalis* females reared from eggs at a constant temperature of 26.7° ± 1°C; photoperiod = 14L:10D; humidity >80%.................... 121

23 Fertility table for *A. gemmatalis* females reared from eggs at a constant temperature of 29.4° ± 1°C; photoperiod = 14L:10D; humidity >80%.................... 122

24 Fertility table for *A. gemmatalis* females reared from eggs at a constant temperature of 32.2° ± 1°C; photoperiod = 14L:10D; humidity >80%.................... 123

25 Fertility table for *A. gemmatalis* females resulted from "laboratory" larvae fed artificial diet and subjected to a variable temperature regime. Photoperiod = 14L:10D; humidity >80%................................ 124

26 Fertility table for *A. gemmatalis* females resulted from "wild" larvae fed on soybean leaves and subjected to a variable temperature regime. Photoperiod = 14L:10D; humidity >80%.................................. 125

27 Fertility table for *A. gemmatalis* females reared from "laboratory" larvae under field conditions.............. 126

28 Daily maximum, minimum, and average temperatures at field insectary when fecundity, egg hatch, and longevity were investigated for females resulted from laboratory larvae under caged conditions on late vegetative soybean stage........................... 127

LIST OF FIGURES

Figures Page

1 (A) - Diagram illustrating the nutritive-endocrine regulation of female reproduction. (B) - Diagram illustrating the main effects of nutrition on reproduction in the female insect. Redrawn from Johansson (1964)...................................... 34

2 Cylindrical wire screen cages used for *A. gemmatalis* oviposition studies....................... 50

3 Average daily consumption and percent average daily consumption for larvae of *A. gemmatalis* fed excised leaves from successive soybean phenological stages. Arrows indicate day at which 50 and 90% cumulative consumption was reached. Temperature = 26.7° ± 1°C; photoperiod = 14L:10D; humidity >80%.... 58

4 Cumulative average egg lay for females resulted from larvae fed excised leaves from successive soybean phenological stages. Temperature = 26.7° ± 1°C; photoperiod = 14L:10D; humidity >80%............ 72

5 Average daily fecundity and percent average daily fecundity for females resulted from larvae fed excised leaves from successive soybean phenological stages. Arrows indicate 50 and 90% cumulative fecundity. A = early vegetative; B = late vegetative stage; C = flowering stage; D = pod set - pod fill stage; and E = senescent stage. Temperature = 26.7° ± 1°C; photoperiod = 14L:10D; humidity >80%....................................... 74

6 Daily average percent egg hatch of *Anticarsia gemmatalis* female adults resulted from larvae fed excised leaves of successive soybean phenological stages. Temperature = 26.7° ± 1°C; photoperiod = 14L:10D; humidity >80%................. 79

7 Percent cumulative mortality for females resulted from larvae fed excised leaves from successive soybean phenological stages. Temperature = 26.7° ± 1°C; photoperiod = 14L:10D; humidity >80%............ 81

8 Cumulative egg lay per mated female at different constant temperatures. Photoperiod = 14L:10D; humidity 80%.. 88

9 Cumulative egg lay per mated female resulted from larvae reared at a variable (laboratory) and field regime. 89

10 Average daily fecundity and percent average daily fecundity for females subjected to different temperature regimes. Arrows indicate 50 and 90% cumulative average fecundity......................... 91

11 Average percent daily egg hatch for females subjected to different constant temperatures......... 96

12 Average percent daily egg hatch for females subjected to a variable temperature regime (oscillation between 22 and 34°C) (wild and laboratory insects) and for females under field conditions............... 97

13 Cumulative average percent mortality for females subjected to different constant temperatures......... 99

14 Cumulative average percent mortality for females subjected to a variable temperature regime (oscillation between 22 and 34°C) and field conditions (average field temperature ca 29.0°C)..... 100

15 Daily leaf area consumption by *A. gemmatalis* larvae fed excised leaves from flowering soybean stage. Temperature = 26.7° ± 1°C; photoperiod = 14L:10D; humidity >80%.............................. 107

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Effects of soybean, *Glycine max* (L.) Merrill, phenology on leaf consumption, development, and oviposition of the velvetbean caterpillar, *Anticarsia gemmatalis* Hubner, was investigated on excised leaflets from five successive stages of 'Bragg' soybean. Phenological stages were designated as early vegetative (V_2 - V_5), late vegetative (V_5 - V_8), flowering (R_1 - R_2), pod set - pod fill (R_4 - R_6), and senescent (R_7 - R_8).

Mean fresh weight consumed by fourth and fifth instar larvae was higher on early than late stages. Trends in mean dry weight consumed did not agree with mean fresh weight consumed due to increases in percent dry matter in individual leaflets as the season progressed. Estimations of leaf area consumed, using bi-weekly ratios of fresh or dry weight to leaf area for 40 unfed leaflets and extrapolating based on fresh or dry weight consumed, proved unreliable under the conditions of the experiment.

Mean larval developmental time varied from 12.64 days on late vegetative to 14.28 days on senescent leaflets. Time from pupa to adult varied from 8.89 to 9.38 days for pod set - pod fill and flowering stage, respectively. Egg hatch to adult varied from 21.87 days on late vegetative to 23.44 days on senescent stage. Larvae fed on senescent stage leaflets produced pupae with reduced weight; however, pupal weight generally was not correlated with consumption and fecundity.

Mean fecundity followed a general trend of higher fecundity at early than late plant stages. Females resulting from larvae feeding on the first four plant stages maintained a high fecundity, with a sharp decrease occurring when larvae fed on supposed nutritionally poor senescent stage leaflets. Results varied from 515.00 eggs/female on senescent leaflets to 963.44 eggs/female on early vegetative leaflets. Average daily fecundity peaked on the fourth day post adult emergence, decreased sharply up to the tenth day, and remained at a low level thereafter. Mean daily egg hatch was high initially but decreased sharply with "aging" of females for all treatments. Longevity varied from 14.06 days for senescent to 17.55 days for flowering stage treatments.

Effect of temperature on *A. gemmatalis* fecundity, egg hatch, and longevity was investigated for different temperature regimes: (1) constant temperatures of 21.1^{o}, 23.9^{o}, 26.7^{o}, 29.4^{o}, and 32.2^{o}C--larvae reared on artificial diet; (2) variable temperatures simulating summer temperatures at Gainesville, Florida--"laboratory" larvae reared on artificial diet and "wild" larvae feeding on pod set - pod fill leaflets; and (3) field temperatures--larvae reared under caged conditions on late vegetative field of soybean.

Mean fecundity was highest at 26.7°C and lowest at 32.2°C, when all treatments were considered. Fecundity at 23.9° and 29.4°C was similar but in both cases, higher than at 21.1°C. Peak average daily oviposition was positively skewed toward early female age and was delayed as temperatures decreased. Mean fecundity for "wild" females was lower than for "laboratory" females under the variable temperature, with the latter being similar to results obtained at 23.9°, 29.4°C, and the field regime. "Laboratory" adults under field conditions laid similar number of eggs to "laboratory" females under the variable temperature regime. Mean egg hatch was lower at 21.1°C when compared to other temperatures. Mean daily egg hatch was high initially, but decreased with "aging" of females. Longevity of females varied from 24.84 days at 21.1°C to 11.21 days at 32.2°C. Longevity of unmated females at 26.7°C differed significantly (longer) from longevity of mated females at the same temperature. Mean fecundity results at all temperatures investigated indicated a much higher fecundity than had been reported previously for *A. gemmatalis*.

INTRODUCTION

Acreage of soybean, *Glycine max* (L.) Merrill, has doubled in the United States from 1960 to 1973, with the greatest rate of increase occurring in southern latitudes and in Brazil the increase in soybean area planted was 10-fold for the same period (Turnipseed and Kogan 1976). This substantial increase in soybean production has occurred in response to increased world-wide demand for high protein food, due to the increasing human population. As pointed out by Evans (1975), edible food crops such as soybean are clearly the major source of both calories and proteins in the human diet and also provide more than two-thirds of the annual production of ca 40 million metric tons of fats and oils.

The rapid increase in area planted to soybean may catalyse drastic changes in arthropod fauna by: (1) displacement of other crops, (2) introduction into cleared woodland, (3) plowing of grasslands, and (4) drainage of previously unproductive swampy lowlands (Turnipseed 1973). Therefore, an increase in planted area may be expected to increase the magnitude of pest problems, especially in the tropical and subtropical areas of the Western Hemisphere where insect pests are of major concern to soybean producers. As stated by Newsom (1978, p. 157), "the challenge to the entomological profession is to prevent the development of new key pests, especially in areas where soybean is at comparatively high hazard from pests."

Pesticides are, and will continue to be, one of the most useful tools in reducing pest populations that have risen above economic threshold levels. However, past and recent experiences have shown that excessive use of broad spectrum pesticides may cause a multitude of adverse effects such as environmental pollution, reduction of natural enemy populations with subsequent resurgence of pests, promotion of secondary pest outbreaks, and development of resistance to pesticides. Awareness of these problems has led researchers and their extension counterparts to develop and adopt integrated pest management systems in which all available tactics for pest "control" are evaluated and compatible components combined to manage pests based on sound ecological, economic, and sociological principles. Under the philosophy of integrated pest management, pesticides are to be used only when necessary and at minimum effective rates.

The complex of insects with damage potential to soybean in the southeastern United States and Brazil is similar. The velvetbean caterpillar, *Anticarsia gemmatalis* Hubner, and the stink bug complex (particularly the southern green stinkbug, *Nezara viridula* L.) are the most serious insect pests in those areas (Williams et al. 1973, Turnipseed and Kogan 1976, Panizzi et al. 1977). Watson (1916) reported *A. gemmatalis* as a major pest of velvetbeans, *Stizolobium deeringianum* Bort., and Nickels (1926) was the first to report this insect as a soybean pest in South Carolina and Florida. Strayer (1973) reported that cost of controlling *A. gemmatalis* in Florida could reach $1.2 million yearly.

To develop effective management programs against insect pests on soybean or other crops, one must have a thorough understanding of plant-insect-environment interrelationships. To accomplish this goal,. an in-depth knowledge of insect ecology and biology as affected by host crop phenology and physical environment clearly becomes a necessity. A number of publications indicate a relationship between host plant phenology and leaf consumption, development, and reproduction of insects (Fitch 1931, Blais 1952, Grison 1958, Tanton 1962, Johansson 1964, Engelmann 1970). Generally, earlier plant phenological stages have been reported as more favorable than later plant stages for consumption, development of the larvae and fecundity of resulting adults. In Brazil, a team of researchers[1] (personal communication) have observed that expansion of the practice of early planting in the state of Parana has resulted in increased *A. gemmatalis* larval populations injuring vegetative stage soybean in certain areas of the state. Therefore, studies on the effect of plant phenology on *A. gemmatalis* biology may provide a greater understanding of velvetbean caterpillar-soybean interactions and subsequent effects on the population dynamics of this pest.

In studies of this nature, effects of temperature and other environmental factors on the biology of insects must be considered. Literature describing the effects of temperature on the life history and population dynamics of insects is too extensive to review thoroughly here. One is referred to the relevant works of Peairs (1927), Andrewartha and Birch (1954), Varley et al. (1973), Sharpe and DeMichele (1977), Barfield et al. (1977a, 1978), Nickle (1977), and Leppla et al. (1977).

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[1] A.R. Panizzi, B.S. Correa, D.L. Gazzoni, E.B. de Oliveira, I.C. Corso, and G.L. Villas Boas. EMBRAPA - CNP Soja, Londrina, Parana, Brazil.

Consumption of excised soybean leaflets and development of *A. gemmatalis* larvae have been investigated by Reid (1975) at four constant temperatures. Even though leaves of different ages (of the same phenological stage) were considered in his studies, consumption and development were not related to successive phenological stages of the soybean crop. Oviposition was not investigated by Reid (1975).

Leppla et al. (1977) studied *A. gemmatalis* life history under laboratory conditions with larvae fed artificial medium. Oviposition was studied at three constant temperatures (21.1°, 26.7°, and 32.2°C) in 20 x 25 cm diameter cylindrical wire screen cages, each containing 25 pairs of adults. However, density of adults in ovipositing cages may reduce insect fecundity as exemplified by Pearl (1932), Henneberry and Kishaba (1966), Engelmann (1970), and Guerra et al. (1972). Obviously, these reports show that insects in isolation had a higher fecundity than did those under more crowded conditions. Collisions, interference with feeding, resting, pairing, and grooming are possible factors in explaining reduced egg production for grouped females (Engelmann 1970). Even though Leppla et al. (1977) demonstrated the effect of temperature on *A. gemmatalis* fecundity, the potential number of eggs laid per female at each temperature may have been altered by grouping the females.

In light of existing literature, a project was initiated to investigate the consequences of soybean plant phenology on the foliage consumption by, development and fecundity of the velvetbean caterpillar. Specific objectives were to: (1) determine the effect of soybean phenological stages on *A. gemmatalis* leaf consumption (weight and leaf area) and development, and the fecundity, egg hatchability, and longevity of resulting females; and (2) study the effect of constant and variable temperature (for field-collected and laboratory-reared insects) on fecundity, egg hatch and longevity of individual females resulting from larvae reared at each of the temperature regimes.

LITERATURE REVIEW

Detailed accounts of the life-history of the velvetbean caterpillar (VBC) have been published by Watson (1915, 1916). Other reports on *A. gemmatalis* life-history are Douglas (1930), Hinds (1930), Hinds and Osterberger (1931), and Ellisor (1942). Greene et al. (1973) studied mating and ovipositional behavior of this insect under field conditions. Laboratory studies of VBC consumption and development have been investigated on soybean and peanut leaves, respectively, by Reid (1975) and Nickle (1977). Laboratory life-history of VBC reared on artificial medium has been reported by Leppla et al. (1977). Strayer (1973) developed economic thresholds and a sequential sampling program for management of *A. gemmatalis*. A computer simulation model for VBC in the soybean agro-ecosystem has been reported (Menke 1973, Menke and Greene (1976). A comprehensive bibliography of literature pertaining to *A. gemmatalis* was compiled by Ford et al. (1975).

Reviews of soybean insects in general were published by Kuitert (1967), Turnipseed (1972a, 1973), and Turnipseed and Kogan (1976). Integrated pest management of soybean arthropods has been discussed by Newsom (1978). A pilot insect pest management program for soybean in Brazil has been reported by Kogan et al. (1977).

Life History

Anticarsia gemmatalis moths lay eggs singly, mostly on the undersurfaces of leaves and less frequently on petioles and stems of velvetbeans, *Stizolobium deeringianum* Bort., (Watson 1916). The same ovipositional behavior was observed on soybean (Ellisor and Graham 1937, Greene et al. 1973). The latter authors observed ovipositing moths flying quickly from one site to another, usually depositing one egg at each location in 2 to 60 seconds. Eggs usually were laid during all dark hours of the night, being most common from 1/2 hr post-sunset until about 2 am EDT. Peak oviposition occurred between 9 and 11 pm EDT. Greene et al. (1973) also reported that oviposition activity was most common after temperature decreased and humidity increased; however, oviposition appeared to diminish when dew began accumulating on the plants.

Eggs of VBC have been described by Watson (1916) as white until about 2 days before hatching when they turn pink and by Ellisor (1942) as pale green initially but gradually darker until a reddish-brown coloration is attained before hatching. During July, August, and September, VBC eggs hatch in ca 3 days (Ellisor 1942), while those laid in November require one week or more or often fail to hatch (Watson 1916). Reid (1975) observed that eggs hatch in 2 to 3 days when maintained at $24^{o} \pm 2^{o}C$, and Leppla et al. (1977) reported that egg hatch occurs between 18 and $33^{o}C$ under laboratory conditions.

Watson (1916) reported that *A. gemmatalis* usually undergoes six larval instars, but that late in the season a few individuals may molt seven times. According to Watson, first and second instar larvae skeletonize leaves by eating the soft material and leaving the veins intact. After the second instar, larvae eat the whole leaf with the possible exception of midribs and larger lateral veins. As reported by Strayer and Greene (1974), the first three larval instars eat very little foliage; whereas, fourth, fifth, and sixth instars inflict the majority of larval injury to soybean. Wide variation in VBC larval coloration has been reported by Watson (1916) and Guyton (1940). Very young larvae are always green, but after the first instar individuals varying from light green to dark colored forms may be found in the field.

Developmental times and descriptions of each larval instar for VBC observed under caged conditions in velvetbean fields were given by Watson (1916). According to Watson, larval development lasted from 20 to 38 days on velvetbeans. Ellisor (1942) reported VBC larval stages lasting ca 3 wk when at temperatures "typical" for the months of July, August, and September. Strayer and Greene (1974) pointed out that the first three larval instars develop in about 4 days and the last three instars develop in about 10 days on soybean during the summer season.

Reid (1975) found that temperature has significantly affected number of molts with VBC larvae passing through five, six, or seven instars depending on temperature. Larvae reared at temperatures above 18.3°C were either five- or six-instar type; whereas, those reared at lower temperatures were six- or seven-instar type. Reid (1975) demonstrated that number of larval molts also can be influenced by soybean leaf age. The proportion of VBC larvae undergoing fewer molts was higher on mature and young than on intermediate-aged foliage.

Mature *A. gemmatalis* larvae fall to the ground and pupate at or slightly below soil surface, under trash, or buried in the soil surface (Hinds 1930). Pupae usually are enclosed in loose cells and complete development in about 7 days in August and 10 to 11 days in September (Watson 1916). Reid (1975) reported that development ranged from 7.7 days at 29.4°C to 19.4 days at 18.3°C for VBC pupae originated from larvae feeding on intermediate-aged soybean leaves under laboratory conditions.

Coloration of pupae changes from an initial light green to a smooth and shining brown when pupae are about one day old. Length and width range from 18 to 20 mm and from 4 to 6 mm, respectively. Adbominal segments are punctuated with fine dots which are particularly thick on the anterior half of each segment, and three pairs of hooked spines are located at the tip of the abdomen (Watson 1916).

Adults of *A. gemmatalis* have been described by Watson (1915, 1916) and Forbes (1954). Adult coloration may vary from a light, yellowish brown to ash gray or a dark reddish brown (Watson 1915). According to Watson, the most distinguishable mark of the color pattern is a line that crosses both wings diagonally near the middle. This line is usually cinnamon in color, edged with dark brown or black.

Forbes (1954) and Greene (1974) reported morphological differences in adult males and females based on the length and form of scales on adult legs. Scales are long and obvious on the femur of the prothoracic legs and tibiae of the metathoracic legs of males; whereas, scales are short and sparce on female legs (Greene 1974). Greene also observed moths from either the field or laboratory; lighter tan moths tended to be females and the darker moths males. However, sex determination by the leg scale method was considered more dependable.

Diurnal flight behavior of VBC has been described as unidirectional with disturbed moths flying in undirected, sharp, and angled patterns; whereas, nocturnal moth movement was directed, slower, and much more controlled (Greene et al. 1973). These authors also suggested pheromone release by females prior to copulation and reported mating activity as consisting of five stages: pheromone release, mating response, mounting by the male, sperm transfer, and separation. Proof of pheromone release by VBC females was given by Johnson (1977). Mating occurs at night with the majority beginning 2 hr post-sunset and considerably fewer after 10 pm EDT (Greene et al. 1973). Leppla (1976) studied mating behavior of VBC under laboratory conditions ($27^{\circ} \pm 1^{\circ}C$). Peak mating occurred during the first 48 hr from adult emergence, continued at a reduced level for the next 6 days, and then declined until the fifteenth day. Egg deposition was not observed before the third day; peak occurred on the fifth day; an intermediate plateau on days 6 to 10; and a subsequent decline that terminated on the eighteenth day. According to Leppla, mating percentage was 94.9%, the number of eggs deposited was 402/female, and an average of 1.7 spermatophores were transferred/female.

Longevity of VBC adults caged on velvetbean was about 5 wk (Watson 1916). According to Watson, the moths' ability to reach far northern regions as Canada may be attributed to their longevity. Watson also calculated that the first moths to reach Gainesville had time to rear four generations and at the same rate they would probably produce nine generations if they remained in the Gainesville area year round. Reid (1975) reported that three generations of *A. gemmatalis* would be possible on soybean at $29.4^{\circ}C$.

Distribution

Anticarsia gemmatalis is considered a pest of major concern in the Western Hemisphere and is regarded as a tropical to subtropical species (Ford et al. 1975). This insect has been reported as a serious pest in the southeastern and gulf coastal states of the United States, Mexico, Surinam, Columbia, Venezuela, Brazil, and the Argentinian provinces of Corrientes and Missiones (Turnipseed and Kogan 1976).

Apparently, *A. gemmatalis* does not survive the winter season in the United States, except in southern Florida where mild climate and presence of suitable hosts year round can support continuous survival and reproduction of this insect (Watson 1916, Buschman et al. 1977a). However, other researchers in Florida (Drs. V.H. Waddill, AREC Homestead; D.J. Schuster, AREC Bradenton; W.H. Denton, AREC Sanford; and E.R. Mitchell, USDA ARS Gainesville) have shown (unpublished data) that *A. gemmatalis* can reproduce continuously on wild host vegetation beyond the freeze line in south Florida. Ongoing experiments of Drs. W.H. Whitcomb and J.L. Stimac[2] (personal communication) indicate that VBC may, in fact, be able to overwinter as pupae in north Florida under some conditions.

Seasonal Occurrence

As hypothesized by Watson (1915, 1916, 1932), *A. gemmatalis* moths apparently migrate northward each summer from southern Florida, which serves as a reservoir for migration or dispersal for this species. However, this hypothesis has yet to be proven and factors triggering initiation and controlling migration of this species remain to be elucidated. Virtually no substantial data exist.

Infestations on soybean have been reported as "seldom reaching economic injury levels north of a line from Arkansas through North

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Carolina" (Turnipseed 1973, p. 551). Moths usually appear at Gainesville, Florida, about the middle of August, but the larvae usually do not occur at damaging levels until early September (Watson 1915, 1916). In a 3-year study of the seasonal occurrence of this insect in north and central Florida, Strayer (1973) pointed out that population peaks occurred in late July, mid August, and early September, with the August and September populations capable of causing economic defoliation. *Anticarsia gemmatalis* has also been reported as not occurring in damaging levels until late August or September in South Carolina (Carner et al. 1974) and in Louisiana (Hinds and Osterberger 1931, Ellisor 1942, Wuensche 1976). According to Hinds and Osterberger (1931), larvae of *A. gemmatalis* were found in very few numbers in Louisiana on June 13, 1930, representing the first generation, and scattered larvae making up the second generation were found in July and August. Herzog (unpublished) found first larvae of the season in south Louisiana on June 19, 19, and 20 in 1974, 1975, and 1976, respectively. Those larvae stripping soybean in September were of the third generation and a fourth generation "dwindled out through October and disappeared before frost" (Hinds and Osterberger 1931). The velvetbean caterpillar was reported as occurring sporadically at damaging levels in North Carolina with populations not generally detected until late August, peak populations occurring between mid and late September (Dietz et al. 1976). Geographical distribution and seasonal abundance of soybean insects were determined by Correa et al. (1977) in six locations throughout the soybean growing area of Brazil. The highest levels of *A. gemmatalis* occurred in January in the northern areas and in February in the southern areas.

Host Plants

Anticarsia gemmatalis host plants, as compiled from the literature, are presented in Table 1. As can be observed from this table, this insect feeds primarily on the family Leguminosae. Exceptions are cotton, wheat, and rice.

With very few exceptions, there have been no in-depth studies with respect to the effects of the different reported hosts on *A. gemmatalis* life-history and population dynamics. Douglas (1930) reported this insect as feeding slightly on cotton *(Gossypium herbaceum* L.) growing adjacent to soybean fields; however, it is not known if larvae completed development on this plant species. Reid (1975) found that larval development took an average of 67 hr longer on kudzu *(Pueraria lobata* Willd.) than on intermediate-aged Bragg soybean foliage at 29.4°C.

Buschman et al. (1977a), studying the winter survival and hosts of the VBC in Florida, indicated that year round oviposition and larval development occurred in south and central Florida. Apparently, this insect did not survive the winter in north central Florida. Among all plants reported, a small vine *Vigna luteola* Jacq. was suggested as the most important winter host because this plant was abundant year round and *A. gemmatalis* larvae were found on it consistently. Other important hosts were *Phaseolus lathyroides* L. and *Dolichos lablab* L. Even though kudzu did not appear to be a reliable winter host for the VBC in most areas in central and south Florida, it was apparently important in supporting VBC populations until they invade soybean and other susceptible crops during the summer.

One of the most important factors limiting the northern limits of *A. gemmatalis* permanent range has been attributed to the effect of low

Table 1. *Anticarsia gemmatalis* host plants.

Scientific Name[a]	Common Name	Source of Reference
Aeschynomenes sp.	Joint vetch	DPI[b]
Agati grandiflora Desv.	Gallito tree or Australian cork-wood tree	Ford et al. (1975)
Arachys hypogaea L.	Peanut	Guyton (1940), Nickel (1958)
Cajanus cajans (L.) Millsp.	Pigeon pea	McCord Jr. (1974)
Cajanus indicus Spreng	Pigeon pea	DPI
Canavalia gladiata (Sav.) de Cond.	Sword bean	Ellisor (1942)
Canavalia maritima Aub.	Horse bean	Buschman et al. (1977a)
Canavalia rosea Sw	Canavalia	Tietz (1972)
Canavalia sp.		Watson (1916), Tietz (1972)
Desmodium floridanum Chapm.	Beggar lice	Buschman et al. (1977a)
Dolichos lablab L.	Hiacinth bean	Buschman et al. (1977a)
Galactia spiciformis Torr. & Gray	Galactia	Buschman et al. (1977a)
Glycine max (L.) Merrill	Soybean	Nickels (1926)
Gossypium herbaceum L.	Cotton	Douglas (1930), Hinds and Osterberger (1931)
Indigofera hirsuta L.	Hairy indigo	Buschman et al. (1977a)
Medicago sativa L.	Alfalfa	Ellisor and Graham (1937)
Oryza sativa L.	Rice	Tarragó et al. (1977)
Pachyrhizus erosus L.	Yam bean	Buschman et al. (1977a)
Phaseolus lathyroides L.	Wild bean or phaseolus	Buschman et al. (1977a)
Phaseolus limensis Macf.	Lima bean	Ford et al. (1975)
Phaseolus semierectus		Tietz (1972)
Phaseolus speciosus	Sweet pea wine	Buschman et al. (1977a)
Phaseolus vulgaris var. *humilis* Alef.	Bush bean	Ford et al. (1975)
Pisum sp.	Field pea or cabbage pea	DPI
Pueraria lobata Willd.	Kudzu	Tietz (1972), Ford et al. (1975), Buschman et al. (1977a)
Pueraria phaseoloides (Roxb.) Benth	Tropical kudzu	Ford et al. (1975)
Pueraria thumbergiana (Siebold & Zucc.) Benth	Kudzu vine	Watson (1916)

Table 1.--continued.

Scientific Name[a]	Common Name	Source of Reference
Rhynchosia minima L.	Least rhyncosia	Buschman et al. (1977a)
Robinia pseudoacacia L.	Black locust	Ellisor (1942), Tietz (1972)
Sesban macrocarpa Muhl.	Coffee weed	Hinds and Osterberger (1931)
Sesbania emerus (Aubl.) Britton & Wilson	Long pod	DPI
Sesbania exaltata Raf.	Sesbania	Tietz (1972)
Stizolobium deeringianum Bort.	Velvetbean	Watson (1916)
Triticum	Wheat	Ford et al. (1975)
Vigna luteola Jacq.	Vigna	Buschman et al. (1977a)
Vigna repens (L.) Kuntze	Cowpea	DPI
Vigna sinensis (L.) Endl.	Cowpea	Hinds and Osterberger (1931)

[a] Scientific names as cited in literature consulted.

[b] Host plant file of the Division of Plant Industry, Florida Department of Agriculture and Consumer Services, Gainesville, Florida.

temperatures on host plants, rather than the direct action of low temperatures on this insect (Watson 1916, 1932). Watson hypothesized that warm periods during the winter season allow adults to emerge, but the absence of suitable hosts at this time precludes maintenance of populations in areas other than southern Florida.

The velvetbean caterpillar appears to have a marked preference for soybean over other hosts (Douglas 1930, Hinds and Osterberger 1931). The latter authors even suggest adoption of the common name "soybean caterpillar" instead of velvetbean caterpillar, due to the decided preference of this insect for soybean when grown adjacent to velvetbeans *(Stizolobium deeringianum* Bort.), cowpea *(Vigna sinensis* (L.) Endl.) and other leguminous host plants.

Natural Enemies

Parasitoids

Watson (1919/1920) reported that extensive observations on the occurrence of *A. gemmatalis* parasitoids revealed that total parasitism of this species was only about 1% during the latter part of September and October. He concluded that internal insect parasitoids were not an appreciable factor in suppressing this insect. Wall and Berberet (1975) found 1.5% parasitism on VBC larvae feeding on peanuts in Oklahoma. A 5% parasitism level was reported on VBC larvae feeding on peanuts in Florida (Nickle 1977). Total VBC parasitism was lowest when compared to other lepidopterous species *(Heliothis zea* Boddie, *Spodoptera exigua* Hubner, *S. frugiperda* Smith, *Feltia subterranea* F., *Pseudoplusia includens* Walker, *Elasmopalpus lignosellus* Zeller, and *Trichoplusia ni* Hubner) occurring on peanuts. Reasons for the apparent lack of significant VBC parasitism have not been elucidated. In Brazil, an ichneumonid of the tribe Gravenhorstiini (presently not further identified) occurs throughout most of the soybean producing areas, reaching high levels of parasitism on VBC in certain locations (Correa 1975). A list, perhaps far from complete, of parasitoids known to attack the velvetbean caterpillar is presented in Table 2. The majority of the parasitoids reported belong to the families Tachinidae, Ichneumonidae, and Braconidae.

Predators

Literature consulted indicates that most insect predators of *A. gemmatalis* belong to the orders Hemiptera, Coleoptera, and Hymenoptera. A list of *A. gemmatalis* predators is presented in Table 3. Watson (1916) reported four pentatomid species preying upon the VBC and emphasized that the most important insect predators of this insect are probably found among the Hemiptera. Turnipseed (1972a) found nabids, geocorids, and spiders as the most abundant predators in soybean fields in South Carolina. Similar findings were reported for soybean fields in Brazil (Correa et al. 1975). Buschman et al. (1977b) presented a list of 20 predators of *A. gemmatalis* eggs in Florida soybean and pointed out that the mean rate of egg predation was 26% in a 24-hr period when eggs were placed in the field. Several bird species have also been reported, in some instances, as important mortality factors on *A. gemmatalis* populations (Watson 1916, Hinds and Osterberger 1931).

Pathogens

The entomogenous fungus *Nomuraea rileyi* (Farlow) Samson has been considered one of the most important naturally occurring factors in

Table 2. Reported parasitoids of *Anticarsia gemmatalis*.

Scientific Name[a]	(Order:Family)	Source of Reference
Apanteles marginiventris Cress.	(Hymenoptera:Braconidae)	Nickle (1977)
Archytas incertus Macquart	(Diptera:Tachinidae)	Correa (1975)
Brachymeria ovata Say	(Hymenoptera:Chalcidae)	Douglas (1930), Nickle (1977)
Ephialtes aequalis Prov.	(Hymenoptera:Ichneumonidae)	Hinds and Osterberger (1931)
Eucelatoria armigera	(Diptera:Tachinidae)	Wall and Berberet (1975)
Eucelatoria sp.	(Diptera:Tachinidae)	Nickle (1977)
Euplectrus chapadae	(Hymenoptera:Eulophidae)	Panizzi et al. (1977)
Euphorocera floridensis Tns.	(Diptera:Tachinidae)	Watson (1916)
Itoplectis rufuscula Davis	(Hymenoptera:Ichneumonidae)	Watson (1916)
Meteorus autographae Muesebeck	(Hymenoptera:Braconidae)	Nickle (1977)
Meteorus leviventris	(Hymenoptera:Braconidae)	Panizzi et al. (1977)
Ophion bilineatum Say	(Hymenoptera:Ichneumonidae)	Hinds and Osterberger (1931)
Patelloa rusti Aldrich	(Diptera:Tachinidae)	Correa et al. (1975)
Patelloa similis Aldrich	(Diptera:Tachinidae)	Panizzi et al. (1977)
Sarchophaga rapax Wal.	(Diptera:Sarcophagidae)	Hinds and Osterberger (1931)
Sturmiini sp.	(Diptera:Tachinidae)	Plank (1944)
Trichogramma minutum Riley	(Hymenoptera:Trichogrammatidae)	Barber (1936)
Voria ruralis Fall.	(Diptera:Tachinidae)	Plank (1944)
Zelomorpha sp.	(Hymenoptera:Braconidae)	Turnipseed and Kogan (1976)
Winthemia archytas	(Diptera:Tachinidae)	Campos Palomino (1965)
Winthemia marmoratum	(Diptera:Tachinidae)	Campos Palomino (1965)
Winthemia rufopicta Big.	(Diptera:Tachinidae)	Hinds and Osterberger (1931)

[a] Scientific names as cited in literature consulted.

Table 3. Insect predators of *Anticarsia gemmatalis*.

Predatory Species[a]	(Order:Family)	Source of Reference
Alcaeorrhynchus grandis Dall.	(Hemiptera:Pentatomidae)	Watson (1916)
Brochymena annulata F.	(Hemiptera:Pentatomidae)	Watson (1916)
Callida decora F.	(Coleoptera:Carabidae)	Dozier (1918)
Callida scutellaris	(Coleoptera:Carabidae)	Correa et al. (1975)
Calosoma granulatum	(Coleoptera:Carabidae)	Correa et al. (1975)
Calosoma sayi Dej.	(Coleoptera:Carabidae)	Dozier (1918), Hinds and Osterberger (1931)
Cardiocondyla nuda minutor Forel	(Hymenoptera:Formicidae)	Buschman et al. (1977b)
Chrysopa rufilabris Burmeister	(Neuroptera:Chrysopidae)	Buschman et al. (1977b)
Conomyrma flavopecta M.R. Smith	(Hymenoptera:Formicidae)	Buschman et al. (1977b)
Doru taeniatum Dohrm	(Dermaptera:Forficulidae)	Buschman et al. (1977b)
Erythemis simplicicollis	(Odonata:Libellulidae)	Neal and Whitcomb (1972)
Euthyrhynchus floridensis L.	(Hemiptera:Pentatomidae)	Watson (1916)
Geocoris spp.	(Hemiptera:Lygaeidae)	Turnipseed (1972a), Correa et al. (1975)
Halticus bractatus Say	(Hemiptera:Miridae)	Buschman et al. (1977b)
Labidura riparia Pallas	(Dermaptera:Labiduridae)	Buschman et al. (1977b)
Monomorium viridum Brown	(Hymenoptera:Formidicae)	Buschman et al. (1977b)
Nabis capsiformis Germar	(Hemiptera:Nabidae)	Buschman et al. (1977b)
Nabis deceptivus Harris	(Hemiptera:Nabidae)	Buschman et al. (1977b)
Nabis roseipennis Reuter	(Hemiptera:Nabidae)	Buschman et al. (1977b)
Orius insidiosus Say	(Hemiptera:Anthocoridae)	Buschman et al. (1977b)
Pachybrachius bilobatus Say	(Hemiptera:Lygaeidae)	Buschman et al. (1977b)
Pheidole dentata Mayr	(~~Hemiptera~~ Hymenoptera:Formicidae)	Buschman et al. (1977b)
Podisus maculiventris Say	(Hemiptera:Pentatomidae)	Watson (1916), Ellisor (1942)
Proxys punctulatus Pallissot de Beauvois	(Hemiptera:Pentatomidae)	Hinds and Osterberger (1931)
Solenopsis geminata F.	(Hymenoptera:Formicidae)	Hinds and Osterberger (1931)
Solenopsis invicta Buren	(Hymenoptera:Formicidae)	Whitcomb et al. (1972)
Spanogonicus albofasciatus Rueter	(Hemiptera:Miridae)	Neal et al. (1972)
Sphex pistipennis Walsh	(Hymenoptera:Sphecidae)	Douglas (1930)
Stiretrus anchorago F.	(Hemiptera:Pentatomidae)	Hinds and Osterberger (1931)

[a] Scientific names as cited in literature consulted.

controlling late season populations of *A. gemmatalis* in the southeastern United States (Watson 1916, Douglas 1930, Hinds and Osterberger 1931, Ellisor and Graham 1937, Allen et al. 1971, Strayer and Greene 1974, Kish and Allen 1978) and in the soybean producing areas of Brazil (Williams et al. 1973, Panizzi et al. 1977).

Even though the above authors agree on the importance and effectiveness of *N. rileyi* in suppressing larval populations of *A. gemmatalis,* this pathogen almost always appears too late to prevent severe VBC defoliation. Allen et al. (1971) suggested that consideration should be given to the artificial dissemination of *N. rileyi* spores to accelerate the initiation of epizootics of this fungus in soybean fields for VBC control. Early attempts to produce accelerated epizootics by introduction of infected larvae in velvetbean fields were unsuccessful (Watson 1916). Early initiation of epizootics on *Trichoplusia ni* (Getzin 1961) and on some soybean insects (Ignoffo et al. 1977) by artificially disseminating *N. rileyi* spores have been reported as successful.

This fungus infected all important species of Lepidoptera which attack soybean in South Carolina (Carner et al. 1975). Kish and Allen (1978) studied the ecology of *N. rileyi* and presented a model for predicting fungus occurrence on *A. gemmatalis* on soybean. Carner et al. (1975) have reported another fungus *Entomophthora* sp. as infecting *A. gemmatalis* larvae in South Carolina.

A nuclear polyhedrosis virus (NPV) which infects *A. gemmatalis* has not been reported to occur in the United States. Steinhaus and Marsh (1962) diagnosed an *A. gemmatalis* NPV from larvae collected on alfalfa in Peru. Nuclear polyhedrosis virus isolates from Brazil have been described by Allen and Knell (1977), Gatti et al. (1977), and Carner and Turnipseed (1977). The efficacy of the NPV in reducing *A. gemmatalis* populations in small field plots have been studied by Moscardi (1977) and Carner and Turnipseed (1977) in Florida and South Carolina, respectively. These authors concur that the virus is very effective against *A. gemmatalis* and has good potential for future use for controlling this pest on soybean.

The spore-forming bacteria *Bacillus thuringiensis* Berliner has been used with some success against several lepidopteran larvae. This pathogen has the advantage over some other pathogens of being readily cultured in artificial medium and available commercially in different formulations (Cantwell 1974). More active strains of this pathogen have given excellent control of *A. gemmatalis* on soybean (Turnipseed 1972a).

Soybean Response to Defoliation and Economic Thresholds for *Anticarsia gemmatalis*

The literature consulted shows that soybean response to artificial and natural defoliations varies with the phenological stage of the plant (Dungan 1939, Kalton et al. 1945, Weber and Caldwell 1966, Todd and Morgan 1972, Turnipseed 1972b, Strayer 1973, Thomas et al. 1974). Dungan (1939) artificially defoliated soybean when plants were in pod and bean development stages. A reduction of more than 95% in yield occurred when 100% of leaves were removed at different times during this stage. Removal of 50% of the leaves reduced yield by 22%. The greatest reduction caused by the 50% defoliation level occurred at the time pods were ca 3.3 cm long and nearly flat. Removal of 50% of the leaves when pods were full length and beans about half grown caused the least effect on yield. Kalton et al. (1945) found that 10 to 75% defoliation on pre-bloom Richland soybean reduced yield only slightly; whereas, 100% defoliation during the same phenological stage reduced yield by 22%. Greatest yield reduction occurred when leaves were removed at the stage where beans started to develop in lower pods. At this stage, defoliations of 10, 25, 50, 75, and 100% caused yield reductions of 8, 13, 18, 36, and 83%, respectively. Fuelleman (1944) defoliated soybean at rates of 30, 50, and 75% at different phenological stages. All rates of defoliation caused severe yield reduction at pod formation and filling stages. Before blooming, 75% defoliation caused significant yield reduction; however, at the other two defoliation levels, no significant reduction was observed. Begum and Eden (1963, 1965) found that defoliation levels of 33, 67, and 100% did not reduce soybean yield significantly when pods were mature; however, all defoliation rates reduced yield significantly when pods were half grown. A 33% defoliation during the blooming stage did not cause a significant effect on yield. Turnipseed (1972b) found similar results with 33% defoliation at bloom and reported that 17% leaf removal at any soybean stage did not reduce yield. A 67% defoliation at beginning of seed enlargement or on a continued basis caused significant yield loss. Results were not affected significantly as a function of variety, planting date, or irrigation.

Yield reductions associated with different levels of defoliation (as well as number of insects necessary to cause such levels) and costs involved in crop production and protection are of paramount importance in determining economic injury levels and economic thresholds for agricultural pests, as exemplified by Strayer (1973). Stern (1973) reviewed the meaning of economic thresholds. This author defined the economic injury level as the lowest pest population density that will cause economic damage. He also defined economic threshold as the density at which control measures should be applied to prevent an increasing pest population from reaching the economic injury level. Rabb (1972), as cited in Luckmann and Metcalf (1975), has suggested some essential factors in the determination of the economic injury level.

Strayer (1973), in economic threshold studies for the velvetbean caterpillar on soybean, reported that the economic injury level was ca 18% defoliation for post-blooming Hutton variety of soybean. The economic thresholds for pre-bloom and post-bloom soybean were determined as 12 large larvae (>1.25 cm long) and 6 large larvae per foot of row, respectively. Similar findings were reported by Thomas et al. (1974) who found that caterpillar populations as high as six larvae per foot of row could be tolerated at post-bloom stages of soybean with less than 2% loss in yield.

Temperature Studies on Insect Biology

The body of literature on the effect of temperature on different aspects of the biology of insects is quite extensive, but one does not need to go through this literature extensively to perceive the very important role temperature plays on the life of insects and other poikilotherms. Peairs (1927) and Sharpe and DeMichele (1977) presented reviews on the effect of temperature on insect development. The former author also investigated development of nine insect species of Lepidoptera, Coleoptera, and Diptera, at constant and variable temperatures.

Temperature is an important component of weather which can produce behavioral and physiological effects on insect populations by modifying the activity of the endocrine system, survival, development, and reproduction (Varley et al. 1973). These authors emphasized that climate (defined as the long term averages of weather patterns) "has a big influence on the mean population density of a species;" (1973, p. 86) whereas, weather (defined as the day to day changes of temperature, humidity, wind, rain, etc.) particularly affects survival and consequently population change.

Under field conditions, the components of weather and other factors affecting development and reproduction of insects are interacting constantly and may be changing independently; therefore, recognizing the effects of any single factor on insect populations is often a very difficult, if not impossible, task. Varley et al. (1973) hypothezised that the optimal conditions for development and reproduction of insects in the laboratory may never be reached in the field. Andrewartha and Birch (1954) discussed in detail the effect of temperature on speed of development, survival and fecundity of animals. They stated that "the range of temperature favorable to any particular species is related to the prevailing temperatures in the places where the animal usually lives" (1954, p. 130) and that the average temperature and its variability are both important in affecting the physiology of a particular animal species. The authors also pointed out that short term fluctuations in temperature within the favorable range of an animal may safely be considered to be equivalent to constant temperatures in this range.

Speed of development of insects usually increases and longevity decreases with increasing temperatures as exemplified by Peairs (1927), Andrewartha and Birch (1954), Shorey et al. (1962), Mitchell (1966, 1967), Engroff and Watson (1975), Tanigoshi et al. (1975), Reid (1975), Barfield et al. (1978), and Barfield and Jones (1979). At temperatures approaching the upper limit of an insect's range (i.e., highest temperature at which some development will still occur), literature shows that there is a reduction in the speed of development (Peairs 1927, Andrewartha and Birch 1954, Sharpe and DeMichele 1977, Barfield et al. 1977a, 1978). Peairs (1927) suggested that this "retardation effect" of high temperatures approaching the upper extreme temperature of a given insect may be due to chemical changes in the chemical condition of the protoplasm, possibly colloidal changes. Such lethal effects are also manifested at very low temperatures (Sharpe and DeMichele 1977). These authors attributed effects of high and low temperatures on insect development to the inactivation of control enzymes. If insects under these conditions do not encounter moderate temperatures, at which "normal" development can be attained, death will occur prematurely (Barfield et al. 1977a).

The rate of development curve may be considered to be a linear function of temperature in the favorable range for development and reproduction of insects. A typical curve depicting rate of development of poikilotherms (cold-blooded organisms) as a function of temperature is presented in Sharpe and DeMichele (1977). There is a region of linearity at median temperatures and regions of departure from linearity as temperatures approach both upper and lower extremes, giving a typical S-shaped appearance to the curve.

A developmental model for poikilotherms, based on thermodynamics of enzyme kinetics, has been reported by Sharpe and DeMichele (1977). The model accounts for both high and low temperature inactivation of hypothesized control enzymes and has been supported by Barfield et al. (1977a, 1978) who presented temperature-dependent models for the parasite *Bracon mellitor* Say and for the fall armyworm, *Spodoptera frugiperda* J.E. Smith, respectively.

The effect of temperature on insect reproduction and longevity has been studied for many insects. Reviews on these aspects have been presented by Andrewartha and Birch (1954) and Engelmann (1970). Literature reveals that peak fecundity is reached at a moderately high temperature of an insect's favorable range for reproduction. As the upper limit is approached, fecundity declines abruptly (Andrewartha and Birch 1954, Jacobson 1965, Toba et al. 1973, Ragusa 1974, Engroff and Watson 1975, Tanigoshi et al. 1975, Leppla et al. 1977). Fye and McAda (1972), however, investigating fecundity of six lepidopterous pests of cotton at 20, 25, 30, and 33^{o}C found that, for all species, fecundity was higher at 20^{o}C. Barfield et al. (1977b), studying fecundity of *Bracon mellitor* at constant temperatures of 15.6, 21.1, 26.7, 32.2, and 37.8^{o}C, observed that maximum cumulative mean fecundity occurred at 26.7^{o}C, but fecundity was not significantly different from 21.1 to 32.2^{o}C.

Peak oviposition of insects is usually skewed toward early ages of adult development and as temperature is increased peak oviposition occurs earlier in the female reproductive cycle. Peak oviposition for *Bracon mellitor* was 17, 11, and 9 days at constant temperatures of 21.1, 26.7, and 32.2^{o}C, respectively (Barfield et al. 1977b). The same trend has been demonstrated by Fye and McAda (1972) for six lepidopterous pests of cotton, by Ragusa (1974) for *Opius concolor siculus* Mon., by Engroff and Watson (1975) for *Bracon kirkpatricki* Wilk., by Tanigoshi et al. (1975) for the McDaniel spider mite *(Tertanychus mcdanielli* McGregor), and by Leppla et al. (1977) for *A. gemmatalis*. The effect of temperature on peak oviposition can be attributed in part to the effect of temperature on pre-oviposition period in insects. Literature mentioned above shows that pre-oviposition period is shortened as temperature is increased.

According to the literature consulted, egg hatch was usually reduced as temperature approached either the upper or lower limit of the favorable temperature range for development and reproduction of insects. Fye and McAda (1972) investigated egg hatch at 20, 25, 30, and 33°C for six lepidopterous species and the general trend for all species was a higher egg hatch at the lower temperatures. As temperature was increased egg hatch was reduced. Toba et al. (1973) reared larvae and resulting adults at 16.6, 21.0, and 27.2°C, and found that egg hatch at these temperatures was 23, 92, and 76%, respectively. Egg hatch for *Rachiplusia ou* Guenee was 29.09, 49.63, and 46.24% at 15.6, 21.1, and 26.7°C, respectively (Mitchell 1966). *Pseudoplusia includens* egg hatch was 89.20, 90.40, and 85.60% at 15.6, 21.1, and 26.7°C, respectively (Mitchell 1967). Leppla et al. (1977) pointed out that 85% of *A. gemmatalis* eggs hatched at 32.2 and 26.7°C, but almost none hatched at 21.1°C.

Effect of temperature on *A. gemmatalis* larval and pupal development have been studied under laboratory conditions by Reid (1975) using soybean leaves, by Nickle (1977) using peanut leaves, and by Leppla et al. (1977) using artificial media to feed the larvae. According to Reid (1975), age at mean adult emergence was estimated as 18, 23, 46, and 90 days at 29.4, 23.9, 18.3, and 15.6°C, respectively, when *A. gemmatalis* larvae fed on intermediate leaves (fully-expanded but immature leaves) of soybean. Mean larval developmental time at these temperatures was 10.7, 13.7, 26.8, and 53.0 days, respectively. Nickle (1977) found that *A. gemmatalis* larval development at 21.1, 23.8, 26.7, 29.4, 32.2, and 35.0°C required 29.7, 25.7, 24.2, 22.5, 21.2, and 20.0 days, respectively. Mean pupal development at these temperatures lasted 14.3, 12.5, 10.0, 8.0, 8.4, and 6.7 days, respectively, and average pupal weights were 0.2601, 0.2596, 0.2214, 0.2692, and 0.2210 g, respectively. A temperature-dependent model for *A. gemmatalis* development is currently being developed by D.W. Johnson[3] (personal communication).

Leppla et al. (1977) determined the incidence, duration, and survival of each stage of *A. gemmatalis* under laboratory conditions at constant temperatures ranging from 10.0 to 37.8°C. Larval development, pupation, emergence, and survival of resulting adults to reproductive age occurred from 13 to 36°C, but larval survival was appreciable only at 21.1, 26.7, and 32.2°C. Mean larval development for males and females was 30.76 and 29.80, 15.54 and 15.74, and 12.53 and 12.38 days at 21.1, 26.7, and 32.2°C, respectively. Male and female mean pupal development, at the same temperature, was 20.69 and 24.37, 9.92 and 9.61, and 7.33 and 6.91 days, respectively. Mean longevity of males and females was 24.60 and 23.39, 14.59 and 13.80, and 6.52 and 6.33 days, respectively. Mating frequencies for these three temperatures were equivalent (96 to 100% mating), and an average of 0.96 to 1.00 spermatophores were transferred per female. Fecundity was highest at 26.7°C (402.78 eggs/female) and lowest at 32.2°C (37.01 eggs/female). At 21.1°C females laid an average of 138.79 eggs/female. Leppla et al. (1977) concluded that "under these constant laboratory conditions 26.7°C was optimum, but the insects did survive and reproduce at temperatures between 21.1 and 32.2°C" (1977, p. 218).

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[3] Mr. D.W. Johnson, Ph.D. Dissertation research, Dept. of Entomol. & Nematol., Univ. of Fla., Gainesville, expected completion 1980.

Reproductive behavior of *A. gemmatalis* has been studied by Leppla (1976) at 26.7°C. Mating activity "peaked during the first 48 hours, occurred at a reduced level for the next 6 days, and continued to decline until the 15th day" (1976, p. 47). No oviposition was observed before the third day. The mean rate of oviposition peaked on day 5 and an intermediate plateau occurred from days 5 to 10 followed by a gradual reduction that terminated on the eighteenth day after adult emergence.

Insect Feeding Studies and Effect of Nutrition on Insect Biology

The knowledge of quantitative and qualitative consumption and feeding behavior of an insect as related to its host is important in understanding the insect's damage potential and degree of association with its hosts (Smith 1959, Tanton 1962, Waldbauer 1962, 1964, Jones and Thurston 1970, Mukerji and Guppy 1970, Reid and Greene 1973, Kogan 1973, Kogan and Cope 1974, Reid 1975, Boldt et al. 1975, Nickle 1977, Capinera 1978). Acceptance of a plant as food by an insect, according to some authors, seems to be governed by the presence or absence of deterrents and "token" feeding stimulants, but some other authors also give emphasis to the nutritional value and balance of nutrients in food plants (Dethier 1954, Fraenkel 1959, Thorsteinson 1960, Waldbauer 1962, 1964, House 1977). The fact that all hosts of an insect are not capable of supporting insect populations at the same level may indicate that on less favorable hosts insects eat less or have a low utilization of the food consumed (Soo Hoo and Fraenkel 1966).

Literature indicates that the typical trend in insect food consumption is toward an increase in proportion of food consumption as larval size increases and, in general, the early instars eat very little with the last two instars accounting for most of the total food consumed (Jones and Thurston 1970, Reid and Greene 1973, Kogan and Cope 1974, Reid 1975, Nickle 1977). Percent cumulative average tobacco leaf eaten by the tobacco hornworm, *Manduca sexta* Johan., was found to be 0.07, 0.32, 1.25, 7.48, and 90.88% by the first, second, third, fourth, and fifth instars, respectively (Jones and Thurston 1970). The soybean looper, *Pseudoplusia includens*, was reported to consume 81.96 cm^2 of soybean foliage at 29.4 1.5°C, the last three instars being responsible for about 97% of the total consumption (Reid and Greene 1973).

Nickle (1977) investigated leaf consumption by six lepidopterous species (*Feltia subterranea* F., *Heliothis zea* Boddie, *P. includens* Walker, *Spodoptera exigua* Hubner, *S. frugiperda* Smith, and *Anticarsia gemmatalis* Hubner) on excised peanut leaves at six temperatures and reported that as temperature decreased, the amount of leaf biomass consumed also decreased. The total leaf biomass consumed per *A. gemmatalis* larva was 1.07, 1.45, 2.14, 2.22, 1.60, and 2.40 g at 35.0, 32.2, 29.4, 26.7, 23.8, and 21.1°C, respectively. Mean consumption by larval instar at 26.7°C was 0.0046, 0.0069, 0.0219, 0.0547, 0.1262, 0.4447, and 0.1384 g for the first and second, third, fourth, fifth, sixth, and seventh instars, and pre-pupa, respectively. Data on fall armyworm, *S. frugiperda*, consumption, development and reproduction for three phenological stages of Runner-type peanuts and vegetative corn have been collected by C.S. Barfield[4] et al. (unpublished). Consumption rates of *S. frugiperda* on Spanish-type peanuts have also been investigated by Smith and Barfield (unpublished).

Reid (1975) determined *A. gemmatalis* larval developmental time and foliage consumption on excised soybean leaflets corresponding to three age categories (young = newly unrolled, pale green leaflets; intermediate = growing leaflets not yet hardening; mature = fully expanded, dark green leaflets) at different temperature regimes. Rate of food consumption depended on the age of the insects and on temperature, but not on foliage maturity. Total area consumed was unaffected by temperature and leaf age, but the larvae consumed more dry and fresh weight as foliage age increased. Cumulative area consumed increased logarithmically with larval age, and the last two instars consumed more than 90% of the total area consumed. The area of intermediate-aged soybean leaflets consumed per larva was 95.1, 103.8, 104.0, and 90.7 cm^2 at 15.6, 18.3, 23.9, and 29.4^{o}C, respectively. According to Reid (1975), temperature and foliage maturity affected the number of molts of *A. gemmatalis* larvae which in turn influence total food consumption. Larvae reared at temperatures higher than 18.3^{o}C were either five- or six-stadia type and at lower temperatures larvae were six- or seven-stadia type. Larvae reared on old and young foliage underwent proportionately fewer molts than larvae reared on intermediate-aged foliage. Those larvae undergoing additional molts consumed more foliage, achieved a larger final size, and produced heavier pupae.

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Boldt et al. (1975) studied consumption of soybean foliage by six lepidopterous pests. For all species tested, ca 90% of the feeding occurred during the final two instars. Consumption by *Trichoplusia ni* was 23 and 32% higher at 25°C than at 20 and 30°C, respectively. Consumption for the species tested was 84.0 cm^2 for *A. gemmatalis*, 119 cm^2 for *T. ni*, 114 cm^2 for *P. includens*, 52 cm^2 for *S. exigua*, 155 cm^2 for *Heliothis virescens* F., and 336 cm^2 for *H. zea*.

Literature reveals considerable attention to the effect of host plants on consumption and biology of insects, most dealing with the ability of an insect to develop and reproduce on different plants within its host range. A few investigations deal specifically with the effect of host phenological stages on insects. As discussed by House (1977), food abundance has been regarded as one of the most important biotic factors in regulating insect populations, but food quality has not been given due consideration. Beck (1956) suggested that the suitability of a given host plant for a particular insect is at least partially dependent upon how well the plant meets the nutritional, chemical feeding, and physical feeding requirements of the insect. Nutritional requirements included only those chemical factors essential to the adequacy of the ingested diet. Chemical feeding requirements were defined as all chemical factors important to normal feeding behavior and physical feeding requirements as all the insect's requirements as far as dietary texture, position, light intensities, and other factors influencing feeding behavior. Other factors considered important in influencing host specificity were: (1) presence or absence of toxic substances in the plant tissue, (2) synchrony of herbivore and plant phenologies, and (3) ovipositional behavior of females.

According to the extensive reviews of Johansson (1964) and Engelmann (1970) on the effect of nutrition on insect reproduction, nutrition of the insect during the larval stage frequently influences fecundity of adult females. Johansson (1964) depicted and discussed the nutritive-endocrine regulation of female reproduction and the main effects of nutrition on female reproduction. His diagrams are reproduced in Figure 1. Labeyrie (1978) discussed the significance of the environment on the control of insect fecundity, and Andrewartha and Birch (1954) have discussed the effect of food quality on speed of development, fecundity, and longevity of insects.

Literature shows that different host plants, different varieties of a certain plant species, and even different phenological stages of the same plant species vary in their ability to support growth and reproduction in insects. Tauber et al. (1945) tested the effect of 30 plant species on reproduction and adult survival of the grasshopper, *Melanoplus bivitatus* (Say). Egg production and survival varied according to host plant, with fecundity varying from 18 eggs/female fed the most unfavorable host to 141 eggs/female fed the most favorable host. In general, higher egg production required greater female longevity. Jacobson and Blakeley (1958) reported that larvae of the pale western cutworm, *Agrotis orthogonia* Morr., fed on wheat produced adults significantly more fecund than did larvae fed barley or oats. Differences observed were attributed to the differential nutritive value of the plant tested. Smith (1959) found that the amounts of Renown wheat, *Triticum aestivum* L., and western wheat grass, *Agropyron smithii* Rydb., consumed by the migratory grasshopper, *Melanoplus bilituratus* Wkr., were approximately the same and twice that of oats, *Avena sativa* L.

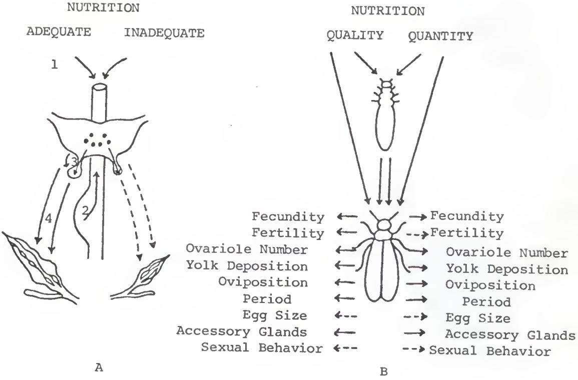


Figure 1. (A) - Diagram illustrating the nutritive-endocrine regulation of female reproduction. After an adequate mean (left side,1) the (nervous?) stimuli from the gut (2) activate the corpus allatum (3) by way of the brain. Hormones from the corpus allatum and from the neurosecretory cells in the brain stimulate the ovaries and accessory glands(4). In the absence of adequate food (right side) the brain inhibits (nervously) the corpus allatum and the hormone titre remains too low for the ovaries and accessory glands to function normally.

(B) - Diagram illustrating the main effects of nutrition on reproduction in the female insect.

Redrawn from Johansson (1964) by Ms. J. Snell.

Oats were considered a poor host because grasshoppers did not consume enough food resulting in high mortality and slow development. Western wheat grass was also found to be a poor host, possibly due to a deficiency of nutrients in the plant tissues because development and weight attained were considered "normal" while mortality was high on this host. Efficiency of conversion of food to body tissue was higher when grasshoppers fed on wheat than on the other two food plants.

Waldbauer (1962, 1964) investigated growth and reproduction of alletectomized tobacco hornworms, *Protoparce sexta (= Manduca sexta* Johan.) on a solanaceous plant, tomato, *Lycopersicon esculentum* Mill., and on non-solanaceous plants which are normally rejected by intact larvae. Growth and reproduction were normal on dandelion, *Taraxacum officinale* Weber, reasonably good on burdock, *Arctium minus* Hill, but poor on mullein, *Verbascum thapsus* L. and *Catalpa speciosa* Warder as compared to tomato. Adverse effects were related to a low rate of feeding which may have been caused by non-nutritive feeding deterrents, but the possibility of an adverse effect due to nutritional deficiency could not be eliminated. Soo Hoo and Fraenkel (1966) conducted feeding studies with the southern armyworm, *Prodenia eridania (= Spodoptera eridania)* Cramer, on 18 different plants from 13 families. They concluded that some of the plants did not support optimal growth because of low digestibility, low conversion efficiency, and low food consumption rate or a combination of these factors.

Mukerji and Guppy (1970) fed different amounts of corn foliage to fifth and sixth instar larvae of *Pseudaletia unipuncta* (Haw.) and found that if the rate of food intake was low but above the threshold, larvae developed but at a slower than normal rate, underwent additional molts, and produced less fecund adults. Kogan (1973) showed that the efficiency of food utilization by the Mexican bean beetle, *Epilachna varivestis* Mulsant, varied considerably among 17 varieties and lines of soybean and five other legumes. Leaf biomass consumed by the beet armyworm, *S. exigua,* has been shown to depend upon the plant species eaten, as exemplified by Hassanein et al. (1971).

Another important consideration is the influence host-plant phenology may exert on different phases of an insect's biology. The physiological condition of the host plant may affect the reproductive capacity of an insect. Fecundity is usually reduced with "aging" of the plant (Johansson 1964). As pointed out by Blais (1952), development, survival, and oviposition of the spruce budworm, *Choristoneura fumiferana* Clem., were altered significantly when larvae fed on two different phenological stages of the balsam fir, *Abies balsamea* (L.) Mill. Field and laboratory studies indicated that when larvae fed on older trees, as opposed to trees with young foliage, mortality was high, development retarded, and fecundity reduced. Fitch (1931) observed that small corn plants (late planted) were less infested by the first generation of European corn borer, *Ostrinia nubilalis* (Hubner), than were large plants (early planted). Small plants were not preferred for oviposition and were unsuitable for larval survival and growth. Beck (1956) tested the influence of certain nutritional factors on *O. nubilalis* larval establishment and development on the corn plant. No evidence was obtained that the unsuitability of young corn plants for borer establishment is related to either a nutritional deficiency or some adverse effect on larval feeding behavior. Grison (1958) found that Colorado potato beetle, *Leptinotarsa decemlineata* (Say), fecundity was reduced significantly when the beetle fed on less-nutritive older leaves of several host species.

The effect of leaf toughness on insect feeding behavior and development was studied by Tanton (1962). He found that larvae of the mustard beetle, *Phaedon cochleariae* Fab., feeding on leaves of turnip, kale, and brussels sprouts, ate larger amounts of less tough (less fibrous) leaves. Larvae feeding on tough (more fibrous) leaves had reduced rates of feeding and growth. Taylor and Bardner (1968) fed leaves of *Plutella maculipennis* Curtis *(= P. xylostella* L.) and *Phaedon cochleariae* Fab. leaves of turnip *(Brassica rapa* L.) and radish *(Raphanus sativus* L.) coming from plants of different ages (4, 6, and 8 wk), and made physical and chemical plant analyses at the different plant stages. Both insect species developed more rapidly on young plants which had less tough leaves and contained a higher protein content that on older leaves. Reid (1975) observed that age of leaves collected from 'Bragg' soybean appeared to have little effect on age at adult emergence of *A. gemmatalis*. However, the effect of leaf age (of the same phenological stage) on VBC oviposition was not investigated by the author.

McWilliams and Beland (1977) reported that larvae of *Heliothis zea* showed a feeding preference for young expanding trifoliates of soybean in the laboratory when compared to larvae feeding on the third, fifth, or seventh trifoliates below the uppermost expanding trifoliate. Development proceeded more rapidly, larvae developed into heavier pupae, and mortality was lower when larvae were fed young expanding trifoliates.

Picard (1926) and Yamashita et al. (1961), as cited in Engelmann (1970), working with the beetle *Haltica ampelophaga* Guer. and the silkworm, *Bombyx mori* L., respectively, observed that late generations of these insects laid fewer eggs than those of the first generation of the year. Engelmann (1970) suggested that these differences could be explained by the fact that later generations had to feed on older plants, which could be less nutritious than those younger plants attacked by the first-generation insects.

Insect oviposition on a phenological stage more suitable for growth and development of the larvae has been observed by Johnson et al. (1975). These authors tested the ovipositional response of *Heliothis zea* to corn, tobacco, cotton, and soybean and found that, for all hosts tested, flowering was the preferred phenological stage. Therefore, oviposition at flowering would insure the availability of fruit for larval feeding. The studies described above clearly demonstrate the importance of host phenological stage on consumption, development, and reproduction of insects. The general trend observed was a reduction in fecundity as plants became older. This aspect of insect-plant interaction has not been studied for the velvetbean caterpillar even though this pest has been reported as the most important defoliator of soybean in southeastern United States and Brazil.

Another factor which seems to be important for normal development, reproduction, and survival of insects is an optimal water content of plant parts being consumed. Soo Hoo and Fraenkel (1966) in their feeding studies with *Prodenia eridania (= Spodoptera eridania* Cramer) on several hosts observed that plants with low water content tended to be an inferior food. Waldbauer (1964) emphasized that tobacco hornworms fed tomato leaves picked in a period of warm and dry weather, which produced serious water stress in plants, ate at a lower rate, digested less of what they ate, and grew at a slower rate when compared to larvae fed leaves picked in a wet period.

The importance of food for adult insects of several species has been reported by many authors. Lukefahr and Griffin (1956) found that adults of the pink bollworm, *Pectinophora gossypiella* (Saund.), when fed various combinations of sugars, laid 37 to 54% more eggs than those adults feeding on water only. Similar observations were made for the army cutworm, *Chorizagrotis auxiliaris* Grote, by Pruess (1963). Shorey (1963) pointed out that as sucrose concentration offered to *Trichoplusia ni* increased, so did fecundity and longevity. Lukefahr and Martin (1964) found that adult food was very important for the tobacco budworm, *Heliothis virescens* F., and the cotton leafworm, *Alabama argillacea* (Hubner). These two species lived about twice as long and laid ca five times as many eggs when adults had access to sugar solution as when supplied only with water. Jensen et al. (1974) reported that fecundity, longevity, and mating frequency increased significantly when adults of *Pseudoplusia includens* Wkr. were provided a carbohydrate food source as opposed to adults having access to water only.

Soybean: Generalities and Nutrient Distribution According to Plant Phenology

Soybean, *Glycine max* (L.) Merrill, belong to the family Leguminosae, is an erect, bushy annual plant which may vary from 0.3 to 2.0 m in height, and may be sparsely or densly branched, depending on cultivar and growing conditions (Carlson 1973). The plant bears from 14 to 26 nodes, the lowest being the one bearing the cotyledons. The next two nodes bear the unifoliate and opposite primary leaves. All other leaves on the stem and lateral branches are alternate, usually trifoliate and borne on long petioles (Shibles et al. 1975).

Fehr and Caviness (1977) described the stages of soybean development and presented a table generalizing the number of days required for plant development from one stage to the next. Time from planting to different stages of growth were ca 10 days (5 to 15) to emergence, 46 days (27 to 79) to bloom, 56 days (32 to 101) to beginning of pod formation, 74 days (41 to 142) to beginning of seed formation, 107 days (61 to 192) to beginning of maturity, and 116 days (68 to 210) to full maturity.

Soybean plants exhibit two common growth habit types: determinance and indeterminance (Shibles et al. 1975, Fehr and Caviness 1977). The indeterminate type generally reach less than half their final height when flowering begins and produce branches while flowering, pod development, and seed development are proceeding. Pod and seed development are more advanced on the lower than on the upper plant parts. The lower leaves are generally larger than those in the upper portion of the plant, thus giving the plant a tapered appearance. Determinate varieties generally have attained most of their height when flowering begins and flowers are formed at approximately the same time in the top and bottom of the plant. After pods are set, the upper leaves are about the same size as the ones in the lower portion of the plant and there is, usually a flowering stalk (raceme) on the terminal node of the main stem.

Leaf area of soybean canopy increases rapidly up to the end of blooming, when a maximum leaf area index of five to eight is attained. After blooming, leaf area index declines to four to six with the approach of physiological maturity and then is reduced abruptly because of progressive yellowing and abscission of leaves as maturity progresses (Shibles et al. 1975). Vegetative dry weight accumulation on soybean plants exhibits an upward trend peaking at about midbean filling. Vegetative and pod dry weight decline during later stages of bean-filling as tissues lose dry weight because of respiration and translocation to the seeds (Hanway and Weber 1971b, Shibles et al. 1975). Temperature, day length, and variety have been reported as important factors in determining the begining of flowering and subsequent reproductive development (Fehr and Caviness 1977). Low temperatures and long days retard, and high temperatures and short days enhance reproductive development.

Flowering, pod, and seed development also have been discussed by Shibles et al. (1975). In brief, flowering occurs over a 4 to 6-week period, depending upon seasonal adaptations, but the sequence of flowering differs with growth habit, as discussed previously. Pods develop slowly for the first few days after fertilization, but a rapid development is initiated at about the fifth day with full pod length being attained by the fifteenth to twentieth day. For most full season plants, the embryo with the first trifoliate leaf already differentiated reaches full size at about 45 to 52 days post fertilization.

Nutrient distribution on soybean plant parts have been studied by several authors and have been reviewed by Ohlrogge (1960) and DeMooy et al. (1973). The latter authors observed that during early stages of soybean development nutrient absorption is rapid in relation to dry matter production and, in consequence, nutrient concentrations are high. Hammond et al. (1951), Henderson and Kamprath (1970), as cited in DeMooy et al. (1973), and Hanway and Weber (1971a) have reported a downward trend in N, P, and K concentration of vegetative parts, as season progressed. Nutrient translocation to the developing seeds resulted in severe nutrient depletion in other plant parts irrespective of fertilizer applications (Hanway and Weber 1971a). Data from Hammond et al. (1951), as cited in DeMooy et al. (1973), show N, P, and K content of leaves at early vegetative stage as about 4.5, 1.5, and 2.6%, respectively. As season progressed, N, P, and K content gradually declined, so that, at maturity it was less than 0.5% for the three nutrients.

Ohlrogge (1960), in his review on trends of nutrient concentration of plant parts according to soybean phenology, reported that 6-day-old seedlings have 8 to 10% N. Nitrogen content declined to 5% in the leaves in about 3 wk and, at bloom, N content was 4%. Phosphorus content varied from 0.5% at early vegetative to 0.25% at bloom stage. Potassium content varied from one to 4% at pre-bloom and from 0.7 to 2% at the flowering stage.

Hanway and Weber (1971a) have shown that, besides a downward trend in nutrient content on vegetative parts as season progresses, there was a wide divergence in percentages of N, P, and K in leaves depending upon their position in the plant. Younger plant parts had higher N, P, and K content than did older parts lower on the stem. Nutrient content on young plant parts was reasonably similar at different times from early vegetative stage to midbean filling. According to Hanway and Weber (1971a), N translocation began in the lower parts of the plant, so that the top portion maintained a relatively high N content until maturity.

METHODS AND MATERIALS

Effect of Soybean Phenology on *A. gemmatalis* Consumption and Biology

General

Consumption, development, and fecundity of *A. gemmatalis* cohorts, as influenced by soybean plant phenology, were investigated under laboratory conditions. Larvae were fed leaflets of successive plant stages throughout the soybean season. Each of the following phenological stages of 'Bragg' variety soybean were used: early vegetative, late vegetative, flowering, pod set to pod fill, and senescent (Table 4). Stages of soybean development were determined in the field as per Fehr and Caviness (1977). Only completely unrolled and developed leaves collected from the upper six nodes of the plant were used in feeding studies. Leaves were collected from 'Bragg' soybean planted 13 June 1978, in Gainesville, Florida.

Table 4. Stages of soybean development (Fehr and Caviness 1977) during laboratory feeding studies with *Anticarsia gemmatalis*.

Stage Denomination	Feeding Started At	Plant Age (days)	Feeding Ended At
Early Vegetative	V_2	17 - 29	V_5
Late Vegetative	V_5	34 - 44	V_8
Flowering	R_1	52 - 63	R_2
Pod Set to Pod Fill	R_4	78 - 89	R_6
Senescent	R_7	97 -109	R_8

No pesticides, with the exception of the pre-emergence herbicide Alachlor (2-chloro-2'.-6'-diethyl-N-(methoxymethyl) acetanalide), were applied to the one-acre field of soybean for the entire season. Therefore, any residue effect that might influence "normal" consumption, development or fecundity of *A. gemmatalis* was avoided. Larvae used in the experiments were obtained from a laboratory culture reared for 24 generations on artificial media (see Greene et al. 1976). Moths were held in Plexiglas® cages equipped with bleached muslin cloth as an oviposition substrate.

Velvetbean caterpillar eggs laid the previous night were collected, washed in a 5% Clorox® solution, neutralized in a 10% sodium thiosulfate solution, and transferred to a paper towel substrate. Pieces of paper containing eggs were cut and taped to the inside lids of 12-oz Dixie® ice cream containers which contained *A. gemmatalis* artificial medium. Containers were then transferred to an environmental chamber at a constant temperature of 26.7° ± 1°C and a 14L:10D photoperiod regimen. Eggs were observed twice daily. When hatch occurred leaves were brought into the laboratory daily and used to feed the larvae.

Plant Phenology and Consumption

Soybean plant stage was determined in the field by a survey of 30 randomly selected plants. At selected soybean phenological stages, leaves and petioles were excised randomly from the upper six nodes of different plants in the field, placed in two Ziploc® plastic bags (26.8 x 27.9 cm), refrigerated, and transported to the laboratory. Leaflets with a petiole of ca 0.5 cm were weighed individually in a Mettler® P163 balance (0.001 g precision), and then inserted in a clip-on cage (25 x 7 mm) (Allen and Pate 1965) filled with moist cotton, and placed in plastic petri dishes (150 x 15 mm). Moist filter paper was placed in the bottom of each dish to maintain leaflet turgidity.

Numbers of larvae/leaflet and numbers of leaflets varied according to larval size and consumption. Since small larvae eat very little, each feeding experiment was started with 20 leaflets, 15 larvae per leaflet, and 10 control leaflets. As larvae increased in size, numbers of leaflets provided for food and controls increased, and number of larvae/leaflet was reduced (Table 5).

Fresh leaflets were weighed daily and fed to larvae. Fresh weight of partially consumed leaflets and controls were recorded daily immediately after larvae were transferred to new leaflets. Subsequently, individual leaflets were placed in small paper bags (size 1) and dried (40.5°C for 24 to 48 hr). Dry weight was obtained for both partially consumed and control leaflets for each day of larval feeding.

Leaf area, taken by an automatic area meter (Haiashi Denko model AAM-S) was obtained twice/week for partially consumed and control leaflets when plants were in the first two phenological stages studied. At flowering, leaf area was measured daily before and after larvae were allowed to feed. Equipment failure prevented measurement of leaf area for the last two plant stages.

Fresh and dry weight of 40 additional leaflets were recorded daily during the feeding tests for each phenological stage. Leaf area was recorded twice weekly on these leaflets for the first three plant stages. Fresh weight consumed was calculated by subtracting weight after feeding from that before, taking into account the water loss by control leaflets. Dry weight of food consumed was calculated daily using the

Table 5. Number of leaflets, initial larvae/leaflet, and control leaflets, used in feeding studies with *A. gemmatalis*, according to plant stage and larval instar.

Plant Stage	*A. gemmatalis* Instar														
	1st Instar			2nd Instar			3rd Instar			4th Instar			5th Instar		
	A*	B**	C***	A	B	C	A	B	C	A	B	C	A	B	C
Early Vegetative	20	15	10	20	15	10	30	5	10	60	3	20	60	1	20
Late Vegetative	20	15	10	20	15	10	20	15	10	60	3	20	60	1	20
Flowering	20	15	10	20	15	10	20	15	10	60	3	20	60	1	20
Pod Set to Pod Fill	20	15	10	20	15	10	20	15	10	60	3	20	60	1	20
Senescent	20	15	10	20	15	10	20	15	10	60	3	20	60	1	20

* A = Number of leaflets

** B = Number of larvae/leaflet

*** C = Number of controls

following formula: (fresh weight before - fresh weight after consumption) x % dry matter of extra leaves.

Data obtained from the additional leaves were used to derive a statistical relationship between fresh or dry weight and leaf area which would allow estimation of leaf area consumed at early and late vegetative and flowering stages.

Plant Phenology and Development

Developmental times from egg to pupation and from pupation to adult emergence were recorded for larvae used in the consumption studies and for additional larvae where consumption was not measured. Until the fifth instar, larvae were not reared individually; therefore, development by instar could not be determined accurately.

Pupation was recorded daily. As larvae ceased feeding prior to pupation, they were transferred individually to 2-oz plastic cups half filled with moist vermiculite as a substrate for pupation. Five-day-old pupae developing from larvae which had fed on each soybean phenological stage were sexed, weighed, and returned to the environmental chamber for subsequent adult emergence observations.

Plant Phenology and Fecundity

Each set of adults developing from larvae which had fed on each soybean plant stage, was placed in a 46 x 38 x 34 cm Plexiglas® cage (Carlyle et al. 1976) and held at 26.7° ± 1°C with >80% relative humidity. Only males and females emerging on the same day were used in the fecundity studies. The ratio of males to females in the cage was always at least one male to each female. Adult food provided in the cage was prepared using 1 g methyl p-hydroxybenzoate, 50 g sucrose, 5 cc unprocessed honey and 0.1 g ascorbic acid per 100 ml of demineralized water (Leppla 1976).

On the third day post-emergence, females were placed individually in cylindrical screen cages (9 x 20 cm) (Fig. 2). Light green paper which was fit to cover the inside surface area of the cage, provided an oviposition substrate. Plastic petri dish tops (9 cm) were used to close each cage at both ends. Fresh adult food was provided to the females every other day in cotton-filled 2-oz plastic cups. Females were maintained under environmental conditions identical to those of the larvae; i.e., constant temperature of 26.7° ± 1°C, >80% humidity, and 14L:10D photoperiod.

Paper substrates were changed daily and eggs deposited by each female were counted. Daily egg counts were made during daylight hours. During scotoperiod, moths were left undisturbed. Papers with eggs were numbered, dated, placed in plastic bags, and returned to the environmental chamber for subsequent egg hatch observations. Daily mortality of females was recorded. Upon death, females were dissected and examined for the presence of spermatophores as evidence of mating. Fecundity, egg hatch, and longevity were computed only for mated females.

Effect of Temperature on *A. gemmatalis* Fecundity

General

Anticarsia gemmatalis fecundity was studied under laboratory conditions at constant temperatures of 21.1°, 23.9°, 26.7°, 29.4°C, and a variable regime simulating average temperatures during "summer" at Gainesville, Florida (roughly, fluctuations between 22° and 34°C). All temperature-fecundity studies were maintained at 14L:10D photoperiod and humidity >80%.

Figure 2. Cylindrical wire screen cages used for *A. gemmatalis* oviposition studies.

Fecundity of adult females reared in cages placed in a soybean field also was investigated. At the variable temperature regime, fecundity of two sets of adults was studied simultaneously. One set was from laboratory-reared larvae fed on artificial medium; the second set was reared from "wild" larvae fed on soybean leaves (variety 'Bragg'; late vegetative stage).

For the constant temperature studies, one-day-old eggs from a laboratory culture were placed in chambers at constant temperatures of 12.8, 15.5, 18.3, 21.1, 23.9, 26.7, 29.4, 32.2, and 35.0°C ± 1°C. Upon eclosion, 150 to 200 larvae corresponding to each temperature were placed individually in 2-oz diet cups and returned to the respective constant temperature chambers. Due to the small number of larvae reaching maturity at temperatures >18.3°C and at 35°C (similar to Leppla et al. 1977), only adults held at constant temperatures ranging from 21.1 to 32.2°C were used in fecundity studies.

For the variable temperature regime, 100 larvae were laboratory-reared in individual 2-oz diet cups. Last instar wild larvae were collected in the field, taken to the laboratory, placed in plastic containers (28 x 16 x 9 cm) and fed fresh leaves every day. Prior to pupation, larvae were transferred to 2-oz plastic cups half-filled with moist vermiculite. Upon emergence, adults were placed in a Plexiglas® cage held in a rearing room at ca 26.7°C ± 1°C and relative humidity >80%. A paper substrate was placed inside the cage for oviposition. Eggs were collected and placed in the variable temperature chamber. Upon eclosion, neonate larvae were placed individually on plastic petri dishes (90 x 15 mm) and provided with fresh leaves daily up to pupation. Resulting adults were then used in fecundity studies.

Constant Temperature Regimes

Pupae produced in the constant temperature chambers were sexed and observed daily for adult emergence. On the day most emergence occurred, adults were placed in a Plexiglas® mating cage without oviposition substrate and then transferred to a rearing room (ca 26.7°C, R.H. >80%). At least one male was placed in the cage with each female.

Adults in the rearing room were observed daily. When eggs were observed on the cage walls, females were placed individually in wire screen cages (9 x 20 cm), provided with a paper substrate for oviposition, and transferred to the respective constant temperature environment. On the first day of oviposition, eggs laid on the cage wall were circled with a marking pen and counted. Number of non-hatching eggs were recorded daily for each female. Longevity was recorded daily for mated females at different constant temperatures. Longevity of unmated females, handled in the same way as mated ones, was studied at 26.7° ± 1°C.

Variable Temperature Regime

Procedures for handling emerging adults, resulting mated females, and oviposition were identical to the above.

Field Study

One-day-old eggs collected from the laboratory culture of *A. gemmatalis* were maintained at 26.7° ± 1°C and, upon eclosion, larvae were transferred to plastic dishes containing field-collected leaves. Larvae and leaves were then taken to the field and placed inside four screen cages (3 x 1.8 x 1.8 m), each covering 6 m of soybean plants (stage V_8). Two hundred and fifty larvae were distributed inside each cage. Cages were inspected daily for adult emergence. Adults emerging on a given day were transferred to a Plexiglas® cage and placed in a screened insectary near the soybean field. Temperature was recorded daily in both field cages and insectary by a hygrothermograph. Eggs were counted and females were transferred individually to small screen cages, as previously described. Daily oviposition, egg hatch, and longevity were recorded for mated females.

RESULTS AND DISCUSSION

Effect of Soybean Phenological Stage on Consumption and Development of *A. gemmatalis*

Mean fresh and dry weight consumed by fourth and fifth instar larvae of *A. gemmatalis* feeding on different phenological stages (Table 4) of 'Bragg' variety of soybean are presented in Table 6. Generally, feeding (fresh weight) declined as plant phenology progressed. Mean fresh weight consumed by fourth instar larvae varied from a mean of 0.137 g at pod set - pod fill stage to a mean of 0.222 g at early vegetative stage. Results were similar for the first two plant stages, but consumption was significantly lower for larvae feeding on leaves from flowering plants than on early vegetative stage leaves. Fourth instar larvae consumed significantly more fresh weight of leaves from senescent plants than on pod set - pod fill stage leaves; however, consumption of leaves of both stages was significantly lower compared to those of the first three plant stages. An interesting point is that fourth instar larvae consumed significantly more fresh weight at senescence than at pod set - pod fill stage. Data for fifth instar larvae show that the reverse occurred, even though differences were not significant ($p > 0.05$).

Fifth instar larvae consumed significantly more fresh weight at the vegetative stages than at the other three sucessive stages. Consumption varied from a mean of 0.786 g on senescent stage to a mean of 1.085 g

Table 6. Mean fresh and dry weight consumed by fourth and fifth instar *A. gemmatalis* larvae fed excised leaves of successive soybean phenological stages. Temperature = 26.7° ± 1°C; photoperiod = 14L:10D; humidity >80%.

Plant Stage	Fourth Instar Larvae[a]		Fifth Instar Larvae[b]	
	Average Fresh Weight Consumed (grams) ± SE[c]	Average Dry Weight Consumed (grams) ± SE[c]	Average Fresh Weight Consumed (grams) ± SE[c]	Average Dry Weight Consumed (grams) ± SE[c]
Early Vegetative	0.222±0.007a	0.0424±0.001b	1.054±0.022a	0.200±0.004b
Late Vegetative	0.210±0.003ab	0.0423±0.0007b	1.085±0.021a	0.219±0.004b
Flowering	0.207±0.005b	0.0483±0.001a	0.888±0.017b	0.209±0.004b
Pod Set - Pod Fill	0.137±0.003d	0.0406±0.001b	0.810±0.055b	0.247±0.017a
Senescent	0.157±0.007c	0.0474±0.002a	0.786±0.068b	0.217±0.019b

[a] 60 dishes per plant stage; 3 larvae per dish on initial day

[b] 60 dishes per plant stage; 1 larvae oer dish on initial day

[c] Numbers followed by the same letter, for a given column, are not significantly different according to Duncan's multiple range test ($p = 0.05$).

on late vegetative stage leaves. Results for early and late vegetative stages were similar and, on both stages, consumption by fifth instar larvae was significantly higher than on the next three successive stages. Consumption decreased from flowering to senescent stage, but results did not differ statistically ($p > 0.05$).

Mean dry weight consumed by fourth instar larvae of *A. gemmatalis* varied from a mean of 0.0406 g for pod set - pod fill leaves to a mean of 0.0483 g for flowering leaves. Significantly more dry weight ($p < 0.05$) was consumed when fourth instar larvae fed on flowering and senescent stage leaves than on any other plant stage. On the other hand, fifth instar larvae consumed significantly more dry weight only when fed pod set - pod fill stage leaves. Differences among the other stages were not statistically significant ($p > 0.05$).

Differences among treatments for mean fresh weight consumed by fourth and fifth instar larvae did not agree with differences obtained for dry weight consumed. This can possibly be explained by the fact that percent dry matter in individual soybean leaves increased with plant age. Therefore, larvae consumed more dry matter per unit leaf fresh weight on older soybean plants. Results also show that dry weight consumption was more uniform than that for fresh weight indicating that larvae may be responding to nutrient and dry matter rather than fresh weight (water).

Reid (1975) showed that temperature and maturity of soybean leaves influenced number of larval molts in *A. gemmatalis* larvae. At temperatures above 18.3°C larvae were either fifth- or sixth-instar type. In the present study, the great majority of larvae passed through five instars, with only very few individuals passing through six instars.

Average daily consumption for larvae feeding on excised leaves corresponding to successive soybean stages is given in Figure 3(A - E). Actual values are presented in Table 10 (Appendix, p.108). Peak consumption occurred on days 11, 9, 9, 9, and 10 for early vegetative, late vegetative, flowering, pod set - pod fill, and senescent stage, respectively. The larval feeding period was 12, 11, 10, 11, and 12 days, respectively, for the successive soybean phenological stages, denoting an apparent higher rate of feeding at intermediate stages than at early vegetative or senescent stages. Peak percent average daily consumption was lower at these two stage (early vegetative and senescent stage), reflecting the slightly extended feeding period in relation to the other stages. For all plant stages, the last two larval instars were responsible for over 90% of total consumption, which is in agreement with Reid (1975) and Nickle (1977) who investigated *A. gemmatalis* consumption on soybean and peanut leaves, respectively.

Arrows in Figure 3 (A-E) indicate days at which ca 50 and 90% of cumulative average consumption was reached for each soybean phenological stage. Fifty percent consumption was reached by days 10, 9, 9, and 9 for the first four phenological stages and on day 9 for the senescent stage. Ninety percent consumption was reached on day 11 for early vegetative, pod set - pod fill, and senescent stage and by day 10 for late vegetative and flowering stages.

In the present study, a second objective was to estimate consumption in terms of leaf area for larvae feeding on the different soybean phenological stages by obtaining a bi-weekly ratio of fresh and dry weight to leaf area from 40 extra leaflets each time and interpreting results in terms of fresh and dry weight consumed. Actual leaf area

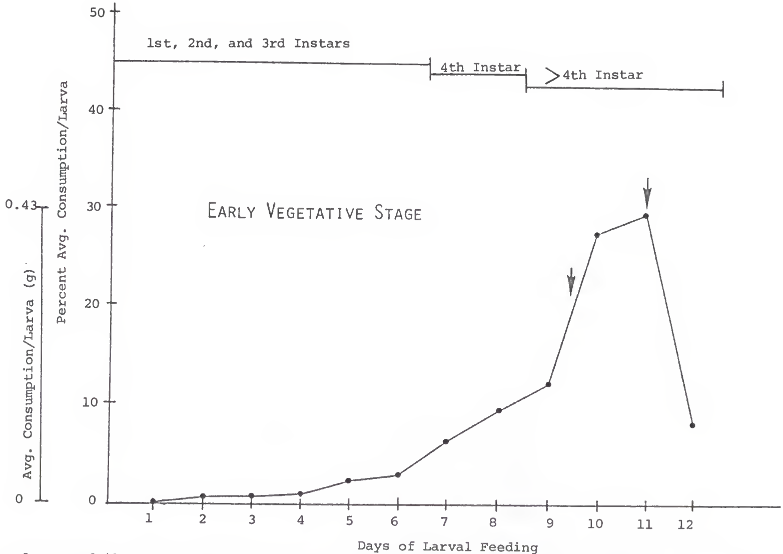
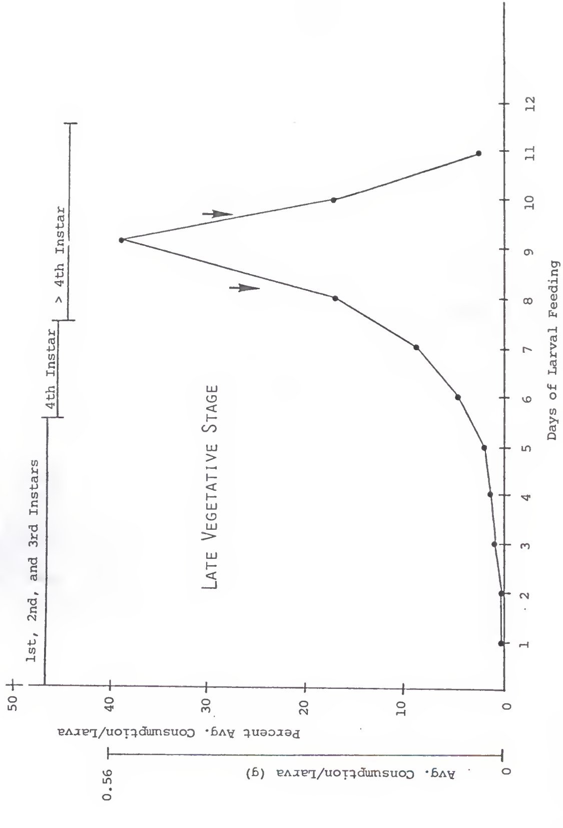


Figure 3. Average daily consumption and percent average daily consumption for larvae of *A. gemmatalis* fed excised leaves from successive soybean phenological stages. Arrows indicate day at which 50 and 90% cumulative consumption was reached. Temperature = 26.7° ± 1 C; photoperiod = 14L:10D; humidity >80%.



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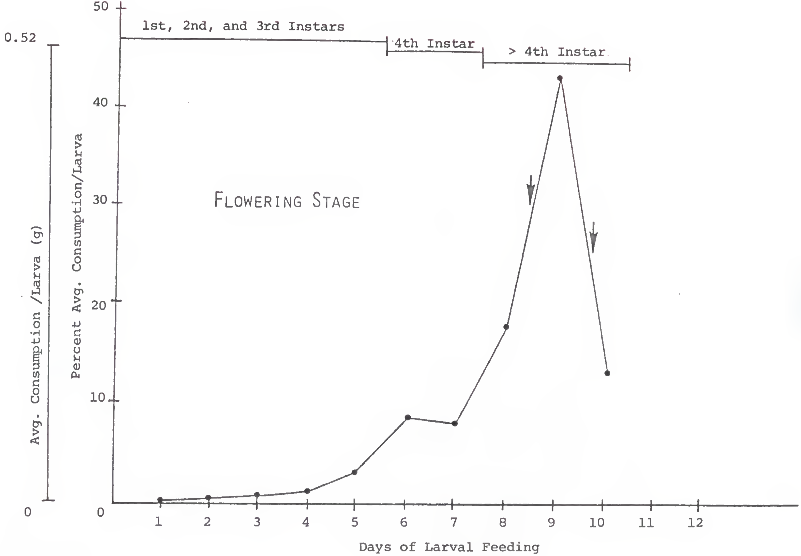

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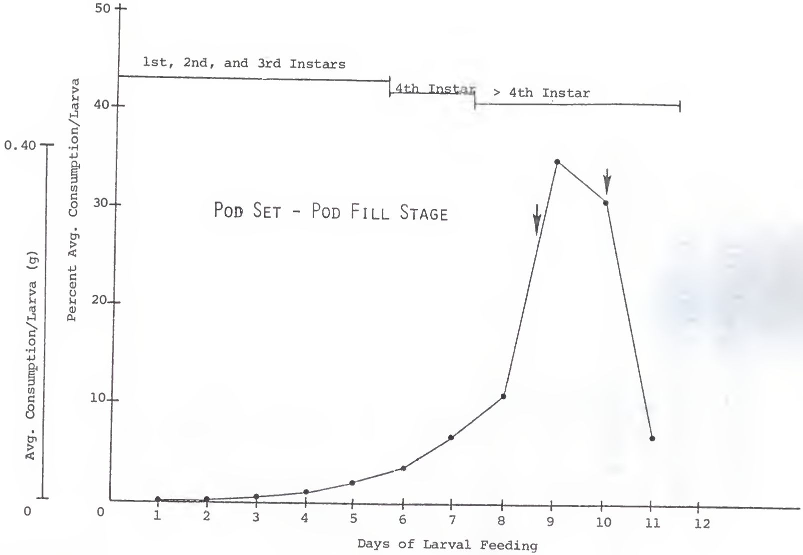

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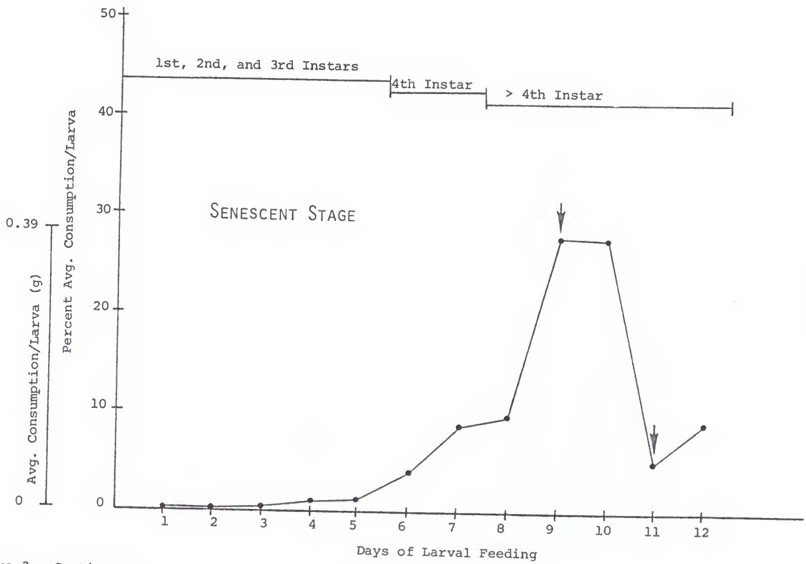


Figure 3.--Continued.

consumed was measured daily at flowering stage as well as bi-weekly measurements of fresh weight, dry weight, and leaf area for 40 extra leaflets in order to compare estimated and observed values to test the validity of the area-weight relationship. However, due to malfunction of the automatic area meter, leaf area could not be measured for the last two phenological stages. Furthermore, the experimental design was probably unreliable under the conditions of the experiment because the ratio of fresh or dry weight to leaf area varied considerably between measurements for the same plant stage. Daily mean leaf areas consumed obtained for larvae feeding on flowering stage leaves are presented in Figure 15 (Appendix). This figure shows that average leaf area consumed was near zero for the first 2 days (first larval instar), increased to about 2.5 cm^2 at day 5 (late third instar), was ca 6 cm^2 for the next 2 days (fourth instar), reached a peak corresponding to ca 35 cm^2 on day 9 followed by a sharp decrease to ca 8 cm^2 on day 10 and the last day of larval feeding.

Mean developmental times from egg hatch to pupa, pupa to adult, and egg hatch to adult, as well as pupal weight and sex ratio for *A. gemmatalis* feeding on successive soybean phenological stages, are given in Table 7. Time from egg to pupa varied from a mean of 12.6 days for larvae feeding on late vegetative stage leaves to a mean of 14.3 days for larvae feeding on senescent stage leaves. Larval development was slower on senescent leaves than on leaves from any other stage, but did not differ significantly ($p > 0.05$) from larval development on early vegetative stage. For flowering and pod set - pod fill stages, results were similar and were significantly faster ($p > 0.05$) than for late vegetative stage. Mean pupal development varied from a mean of 8.9 days

Table 7. Hatching to pupa, pupa to adult, hatching to adult mean developmental times, pupal weight, and sex ratio for *A. gemmatalis* larvae fed excised leaves of successive soybean phenological stages. Temperature = $26.7^{o} \pm 1^{o}$C; photoperiod = 14L:10D; humidity >80%.

Plant Stage	No. Observations	Mean Time From Egg Hatch to Pupa (days) ± SE	Mean Time From Pupa to Adult (days) ± SE	Mean Time From Egg Hatch to Adult (days) ± SE	Mean Pupal Weight (grams) ± SE	Sex Ratio Male/ Female
Early Vegetative	111	13.89±0.25a	9.22±0.06b	23.11±0.25a	0.252±0.002b	1.22
Late Vegetative	128	12.64±0.05c	9.23±0.06b	21.87±0.07c	0.265±0.002a	1.37
Flowering	222	13.30±0.04b	9.38±0.05a	22.68±0.07b	0.251±0.002b	0.83
Pod Set - Pod Fill	99	13.06±0.20b	8.89±0.08c	21.95±0.22c	0.242±0.003c	0.98
Senescent	68	14.28±0.09a	9.16±0.09b	23.44±0.15a	0.228±0.003d	1.12

[a] Means followed by the same letter, for any given column, are not significantly different according to Duncan's multiple range test ($p = 0.05$).

for pod set - pod fill stage to a mean of 9.4 days for flowering stage. Pupae produced by larvae feeding on flowering stage leaflets had significantly longer ($p < 0.05$) mean developmental times than those produced by larvae feeding on leaves of any other phenological stage. On the other hand, results for pod set - pod fill stage were significantly faster ($p < 0.05$) than for any other plant stage. No significant differences ($p > 0.05$) in mean pupal development were observed for early vegetative, late vegetative, and senescent stages. Mean days from hatch to adult emergence varied from a mean of 21.9 days for *A. gemmatalis* larvae feeding on late vegetative stage leaves to a mean of 23.4 days when larvae fed on senescent stage leaves. Mean days from egg hatch to adult emergence did not differ significantly ($p > 0.05$) for early vegetative stage and senescent stages. Results obtained for late vegetative stage and pod set - pod fill stages were similar but were significantly lower ($p < 0.05$) than for flowering stage. Mean pupal weight varied from a mean of 0.228 g when larvae fed on senescent stage leaves to a mean of 0.265 g when larvae fed on late vegetative stage leaves. Results for late vegetative and senescent stages were significantly higher and significantly lower ($p < 0.05$), respectively, than results obtained for any other plant stage. Similar mean pupal weights were obtained for early and flowering stages. Sex ratio (male/female) was ca 1.0 at all plant stages studied and varied from 0.83 for adults originating from larvae fed on flowering stage leaves to 1.27 for insects originating from larvae fed on late vegetative stage leaves. Results for consumption and development of *A. gemmatalis* as influenced by soybean phenological stage show that mean fresh weight consumption by *A. gemmatalis* larvae was approximately equal for the first two plant stages but generally decreased for successive later stages. Periods of larval feeding and peak average consumption differed for the different plant stages. Plant stage apparently had little effect on development or on mean age at adult emergence.

Literature specifically describing the effect of crop phenological stages on consumption is sparce. Most of the literature existing on insect-host phenology relationships report effects on larval development and adult fecundity. As shown by Taylor and Bardner (1968), larvae of *Plutella maculipennis (= P. xylostella* L.) and *Phaedon cochleariae* Fab., when fed leaves from successive stages of turnip and radish, ate a greater weight of old than of young leaves. On the other hand, Barfield et al. (unpublished) have shown that larvae of the fall armyworm, *S. frugiperda*, fed excised leaves from three successive stages of peanuts consumed significantly more fresh weight on the intermediate stage than on early or late plant stages. These studies, in conjunction with the present study, apparently indicate that trend in fresh weight consumption by an insect on successive plant phenological stages may be dependent on insect-plant relationships unique to a given system. The insects may consume more fresh weight on a specific phenological stage of a given plant species, depending on physical environment and characteristic physiological and physical properties of the leaf being consumed (Tanton 1962, Waldbauer 1964, Soo Hoo and Fraenkel 1966, Taylor and Bardner 1968). Consumption in a dry weight basis appears to be important since *A. gemmatalis* dry weight consumption was more uniform than that of fresh weight for all plant stages.

Higher nutrient content of individual leaves at early soybean stages (Hanway and Weber 1971a, Hammond et al. 1951, Henderson and Kamprath

1970), associated with other physiological changes and an increase in leaf "toughness" as season progressed, may have caused *A. gemmatalis* larvae to consume less fresh weight at successive later stages of soybean phenology. The effect of soybean phenological stage on *A. gemmatalis*, through the differential nutritive value associated with physical and physiological properties of leaves, was more evident on consumption than on insect development. The combination of differential nutritive value and varying consumption for different soybean phenological stages may have caused the results observed on *A. gemmatalis* fecundity.

Effect of Soybean Phenological Stage on Fecundity, Egg Hatch, and Longevity of Adult *A. gemmatalis*

Mean fecundity, percent egg hatch, longevity and net reproductive rate (Ro) for females produced by larvae feeding on excised leaves of successive soybean phenological stages are given in Table 8. Total fecundity per female is presented in Table 11 (Appendix, p. 109). Mean fecundity varied from a mean of 515 eggs/female when larvae fed on senescent stage leaves to a mean of 963.41 eggs/female when larvae fed on early vegetative stage leaves. Larvae fed early vegetative stage leaves produced adults with significantly higher fecundities ($p < 0.05$) than those adults produced from larvae which fed on leaves of any of the three last plant stages (flowering to senescent). Results for senescent stage were significantly lower than results for all other plant stages. Mean fecundity declined from early vegetative to senescent stage, except for pod set - pod fill stage which produced females with higher fecundity than for the flowering stage. Results obtained for pod set - pod fill stage increased , probably due to a higher concentration of leaf sugars in soybean leaves during this period. However,

Table 8. Mean fecundity, egg hatch, longevity and net reproductive rate (Ro) for *A. gemmatalis* females resulted from larvae fed excised leaves of successive soybean phenological stages. Temperature = 26.7° ± 1°C; photoperiod = 14L:10D; humidity >80%.

Plant Stage	No. of Mated Females	Mean Eggs/Female ± SE[a]	Mean % Egg Hatch ± SE[a]	Mean Longevity (days) ± SE[a]	Ro[b]
Early Vegetative	22	963.41±51.66a	71.06±2.55b	16.91±0.70ab	364.82
Late Vegetative	28	895.46±41.75ab	73.64±1.63ab	17.39±1.10a	346.15
Flowering	31	759.68±36.13c	74.21±1.79ab	17.55±0.97a	304.23
Pod Set - Pod Fill	21	820.29±35.18bc	77.46±1.74a	16.38±1.09ab	330.23
Senescent	16	515.00±21.53	75.47±1.53ab	14.06±0.83b	199.24

[a] Means followed by the same letter, on any given column, are not significantly different according to Duncan's multiple range test (p = 0.05).

[b] Ro = net reproductive rate (Laughlin 1965) (for more details see tables 13 to 17, Appendix).

results for flowering and pod set - pod fill stage did not differ significantly ($p > 0.05$).

Results generally agree with findings by other authors (Blais 1952, Grison 1958, Johansson 1964, Engelmann 1970) who reported a reduction in insect fecundity with "aging" of plants. Adverse effects were often attributed to reduced nutritive value of later plant stage leaves. Present results show that even though there was a general decline in mean fecundity of *A. gemmatalis* adults when larvae fed on successive soybean phenological stages, females maintained a relatively high fecundity through all stages, with the clear exception for senescent stage when a sudden decrease occurred.

Investigations by Hanway and Weber (1971a, 1971b), Hammond et al. (1951), and Henderson and Kamprath (1970) show a downward trend in N, P, and K concentration of vegetative parts (all leaves considered) of soybean as season progressed. However, Hanway and Weber (1971b) have shown that there was a wide divergence in N, P, and K percentages in leaves depending upon position on the same plant. Younger plant parts had higher nutrient content than did older parts lower on the stem. Furthermore, the authors emphasized that top portions of soybean plants maintained a relatively high N content until maturity. These findings may explain the "relatively high" mean fecundity maintained by *A. gemmatalis* females when larvae were fed on leaves corresponding to the first four phenological stages. Leaves fed to larvae always were collected from the top third of the plant. Another interesting aspect is that findings by Hanway and Weber (1971b) seem to be in accord with the feeding behavior of *A. gemmatalis* larvae which feed primarily on the top portion of soybean plants (Reid 1975). In fact, close field observation at the time the present research was conducted confirmed these results. Given a choice, larvae fed on more tender leaves in the top portion of the plant leaving "tougher" leaves lower on the stem almost untouched.

Observed differences in mean fecundity of *A. gemmatalis* could have been caused by a decrease in nutrient content of top leaves. Another possible explanation could be reduced consumption of soybean leaf biomass, with "aging" of the plants, by larvae feeding on successive phenological stage up to pod set - pod fill stage. The sudden decrease in mean fecundity for adults arising from larvae fed on senescent stage leaves may be attributed mainly to the poor nutritional quality of leaves at this stage.

Mean percent egg hatch (Table 8) varied from 71.06% for adults whose larval stage fed on early vegetative stage treatment to 77.46% for those feeding on pod set - pod fill treatment. Results suggest that soybean crop phenology did not have an appreciable effect on egg hatch even though eggs laid by females resulting from larvae feeding at early vegetative stage had a lower mean hatch than the other successive stages. However, hatch of eggs corresponding to this stage was significantly different ($p < 0.05$) only as compared to the same parameter at the pod set - pod fill stage. Results were similar for the last four plant stages.

Mean longevity of mated females varied from 14.1 days when larvae fed on senescent stage leaflets to 17.6 days when larvae fed on flowering stage leaflets. Similar results were obtained for the first four plant stages. Mean longevity of females resulting from larvae fed senescent stage leaves was significantly lower ($p < 0.05$) only when compared to late vegetative and flowering stage values. Slightly lower longevity of females originated from larvae fed senescent stage leaves might have been caused by lesser amount of nutritive reserves carried over to adult stage due to poor nutritive value of the leaves.

Net reproductive rate (Ro) (Table 8) was computed from fertility tables (Southwood 1978) constructed for adult females resulting from larvae feeding on each phenological stage (more details in Tables 13 to 17, p. 111-115, Appendix). Values varied from 199.24 when larvae fed on senescent stage leaflets to 364.82 when larvae fed on early vegetative stage leaves. All values were higher than the Ro value given by Leppla et al. for *A. gemmatalis* adults reared from larvae fed artificial diet at 26.7°C.

Cumulative average daily egg lay for females corresponding to each phenological stage is shown in Figure 4 (actual values can be derived from Table 11, p. 109, Appendix) and serves to illustrate differences obtained for mean fecundity, as discussed previously. Females resulting from larvae feeding on early vegetative stage leaves had a higher cumulative average fecundity than those from larvae feeding on any other plant stage. However, a much lower cumulative average fecundity of females resulted when larvae fed on senescent stage leaves. Cumulative average fecundity increased sharply up to day 6 to 8 post female emergence for all treatments, followed by a more gradual increase thereafter until maximum cumulative fecundity value was reached.

Figure 5 (A - E) depicts average fecundity and percent average fecundity in relation to days from adult emergence and percent of total oviposition period for adults resulting from larvae fed excised leaves of successive soybean phenological stages. Arrows in Figure 5 indicate

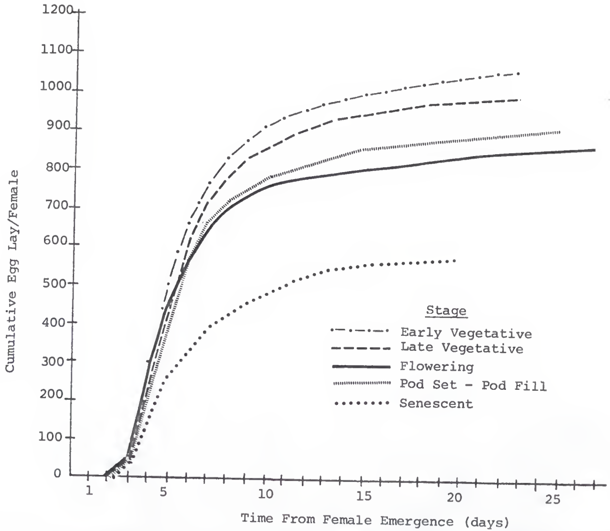
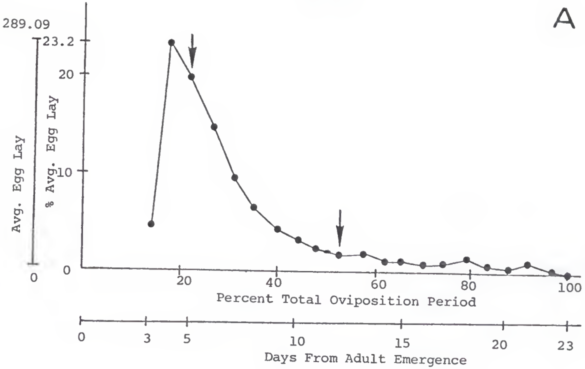


Figure 4. Cumulative average egg lay for females resulted from larvae fed excised leaves from successive soybean phenological stages. Temperature = 26.7° ± 1°C; photoperiod = 14L:10D; humidity >80%.

Figure 5. Average daily fecundity and percent average daily fecundity for females resulted from larvae fed excised leaves from successive soybean phenological stages. Arrows indicate 50 and 90% cumulative fecundity. A = early vegetative stage; B = late vegetative stage; C = flowering stage; D = pod set - pod fill stage; and E = senescent stage. Temperature = 26.7° ± 1°C; photoperiod = 14L:10D; humidity >80%.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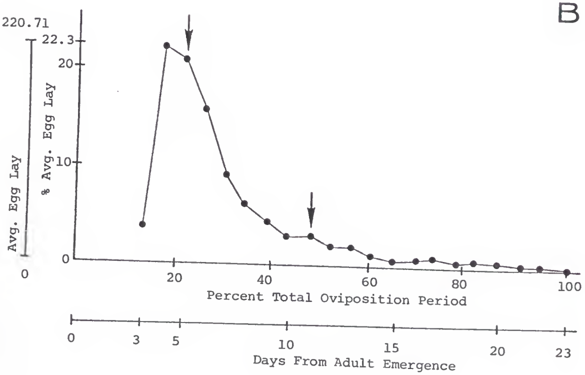
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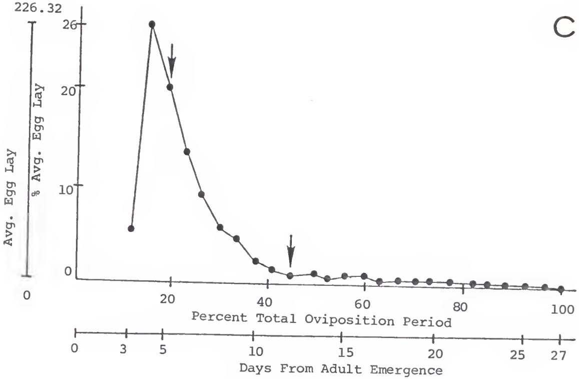
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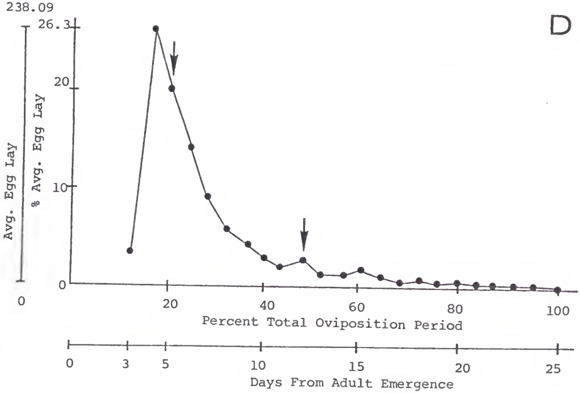
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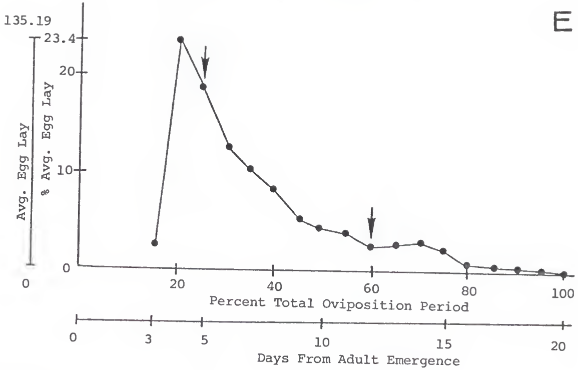
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Days From Adult Emergence

day or percentage of total oviposition period at which 50 and 90% of cumulative mean fecundity was reached. Actual values can be extracted or derived from Tables 13 to 17 (Appendix, p.111-115). Peak average fecundity occurred on the fourth day post adult emergence for adults resulting from larvae fed on any of the plant stages. Magnitude of the peak, however, varied from 135.19 eggs/female for senescent stage to 248.09 eggs/female for early vegetative stage. A sharp decrease in average fecundity occurred following day 4 for females produced from larvae which fed on any of the first four soybean stages. Average fecundity fell to ca 3 eggs/female on day 10 and remained at a low level thereafter. Results for senescent stage show that average fecundity fell somewhat more gradually up to day 10.

Peak percent average fecundity was 23.2, 22.3, 26.0, 26.3, and 23.4% and occurred at ca 17, 17, 14, 16, and 20% of the total oviposition period for females resulting from larvae feeding on the successive soybean stages. Fifty percent of the eggs were laid approximately in the first 5 days post emergence of females resulting from larvae feeding on any of the plant stages. Cumulative 90% of the eggs laid occurred on day 12, 11, 12, 12, and 12 for the successive stages of soybean. In terms of percentage of total oviposition period, 50% of the eggs had been laid when 20 to 25% of the female oviposition period had passed for all treatments.

Results indicate that soybean phenological stage did not have any effect on day of peak average fecundity. Magnitude of the peak, however, generally decreased with "aging" of the plant with a much smaller peak occurring for females resulting from larvae fed on senescent stage leaves. Daily ovipositional behavior of *A. gemmatalis* generally agreed with results obtained by Leppla (1976) and Leppla et al. (1977) who studied *A. gemmatalis* fecundity for adults resulting from larvae reared on artificial diet at the same temperature (26.7°C) utilized in the present study. Peak average oviposition occurred on the fourth day post adult emergence, as opposed to a peak on the fifth day (Leppla et al. 1977). Mean fecundity values obtained in the present study were much higher than the value of 402 eggs/female reported by Leppla (1976) and Leppla et al. (1977).

Percent average egg hatch in function of female age, is given in Figure 6 and shows a decline in percent egg hatch with "aging" of females for all treatments. Values were ca 81 to 90% initially and remained high up to day 6 followed by a sharp decrease to ca 15.25% on day 11 post emergence. Thereafter, average percent egg hatch remained at a low leve.

Percent cumulative mortality for females resulting from larvae fed on excised leaflets of successive soybean phenological stages is presented in Figure 7. Females corresponding to senescent stage died at a faster rate and reached 100% mortality sooner than females corresponding to larvae fed on the other four stages. However, as discussed previously, results for senescent stage were only significantly different ($p < 0.05$) from those corresponding to late vegetative and flowering stages.

The annual occurrence of *A. gemmatalis* in significant numbers most frequently coincides with the flowering stage of soybean in Florida (Strayer 1973) and in South Carolina (Turnipseed 1973). In the present study, early phenological stages are shown as apparently the best food for this insect. Winter survival, dispersal, and the mechanisms controlling dispersal of this insect are not well understood. Reports by

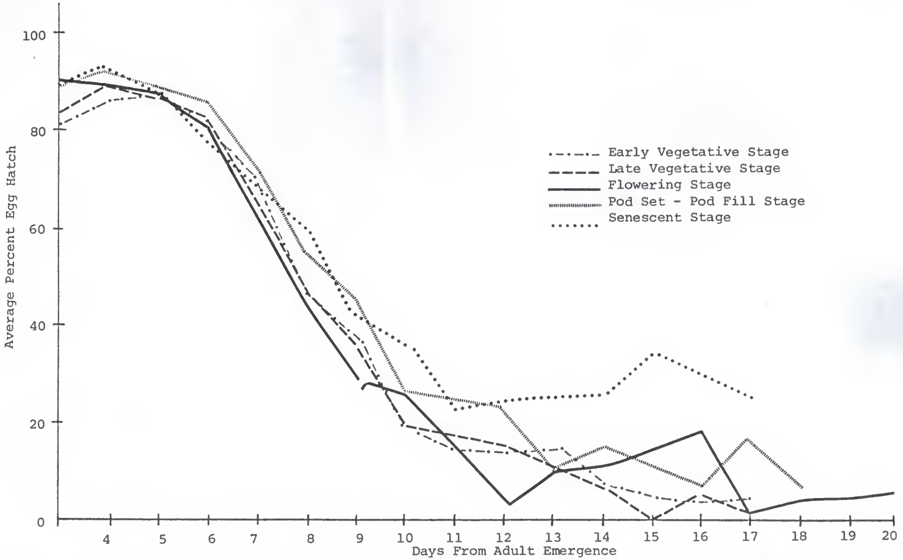
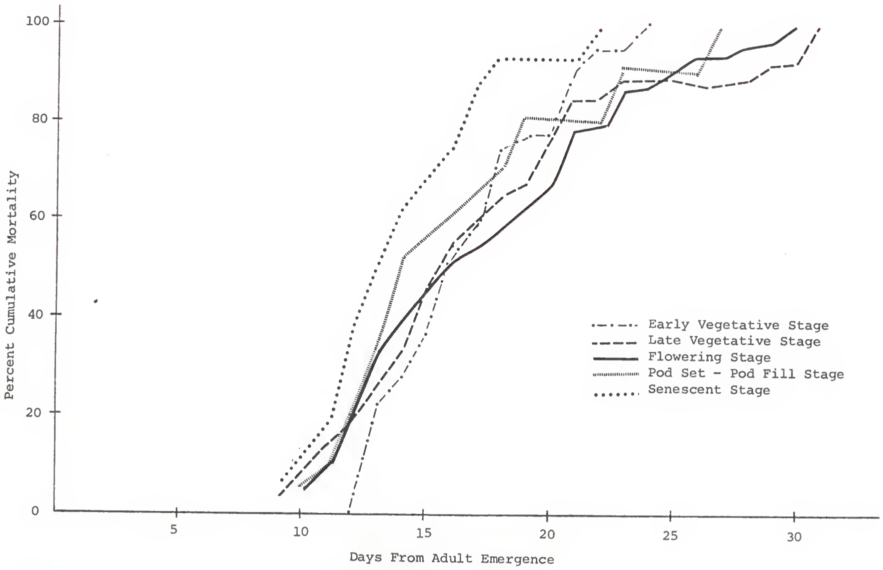


Figure 6. Daily average percent egg hatch of *Anticarsia gemmatalis* female adults resulted from larvae fed excised leaves of successive soybean phenological stages. Temperature = 26.7° ± 1°C; photoperiod = 14L:10D; humidity >80%.

Figure 7. Percent cumulative mortality for females resulted from larvae fed excised leaves from successive soybean phenological stages. Temperature = $26.7^{\circ} \pm 1^{\circ}C$; photoperiod = 14L:10D; humidity >80%.


100
80
60
40
20
0
Percent Cumulative Mortality
5
10
15
20
25
30
Days From Adult Emergence
Early Vegetative Stage
Late Vegetative Stage
Flowering Stage
Pod Set - Pod Fill Stage
Senescent Stage

Watson (1915, 1916) and Buschman et al. (1977a) indicate that *A. gemmatalis* apparently survive the winter on wild host plants in south Florida, but more in depth host plant-insect relationships are not known. Therefore, there is the possibility that the significant numbers of larvae often observed after flowering may be related mainly to the inability of moths to reach soybean producing areas in north Florida before that time. Natural scattering of hosts and possibly low nutritional value of wild plants serving as hosts in south Florida would preclude a rapid build-up of *A. gemmatalis* populations. However, if the area planted to soybean in Florida continues to extend further south, these relationships might be altered.

Results obtained on effect of soybean phenological stage on leaf consumption, development, and fecundity under controlled laboratory conditions indicated that plant stage did affect this insect differentially. However, under natural ecosystem conditions a multitude of other factors interact to bring about population changes. Hopefully, the investigations under laboratory conditions of plant phenology effect on *A. gemmatalis*, as well as the isolated effect of temperature presented in the next section, will help future workers on other needed investigations for a better understanding of this insect's population dynamics under natural conditions.

Effect of Temperature on Oviposition, Egg Hatch, and Longevity of *A. gemmatalis*

Mean fecundity, egg hatch, longevity, and net reproductive rate (Ro) for *A. gemmatalis* adult females under different temperature regimes are given in Table 9. Mean fecundity varied from 310.0 at 32.2°C to

Table 9. Mean fecundity, egg hatch, longevity, and net reproductive rate (Ro) for *A. gemmatalis* females reared from eggs at different temperature regimes. Photoperiod = 14L:10D; humidity >80% except for field experiment.

Temperature (°C)	No. of Mated Females	Mean Eggs/Female ±SE[a]	Mean % Egg Hatch ± SE[a]	Mean Longevity (days) ± SE[a]	Ro[b]
21.1	19	482.84±21.32c	68.60±0.88d	24.84±0.99a	179.68
23.9	29	732.31±22.86b	77.40±1.10c	21.96±0.94b	304.41
26.7	25	842.16±26.08a	82.31±1.44ab	18.00±0.95c	369.00
29.4	15	713.47±28.06b	78.51±1.34bc	15.47±0.66cd	295.40
32.2	19	310.00±14.70d	80.81±0.69bc	11.21±0.62e	135.11
Var. A[c]	15	695.13±42.25b	80.54±2.06bc	15.53±0.83cd	297.65
Var. B[d]	15	559.00±26.55c	85.71±1.77a	16.33±0.67c	254.54
Field[e]	12	716.17±43.65b	78.04±2.48bc	12.03±0.80de	298.35
26.7[f] Unmated Females	46	-	-	22.76±0.81ab	-

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[a] Means followed by the same letter, on any given column, are not significantly different according to Duncan's multiple range test ($p = 0.05$).

[b] Net reproductive rate (see Laughlin 1965) (for more details see tables 20 to 27, Appendix).

[c] Average temperatures during "summer" at Gainesville, Florida (roughly, fluctuations between 22° and 34°C) - "laboratory" insects.

[d] Same temperature regime as above - "wild" insects.

[e] Adults reared from larvae under caged conditions on late vegetative soybean stage. Average field temperature was ca 29.0°C during the test period (see table 28, Appendix).

[f] Shown only to depict longevity.

842.16 at 26.7°C (Table 18, Appendix, shows total fecundity per individual female at each temperature regime). *Anticarsia gemmatalis* females laid significantly more eggs at a constant temperature of 26.7°C than at any other regime investigated. At intermediate constant temperatures of 23.9° and 29.4°C, mean fecundity was similar and not significantly different ($p > 0.05$). At the extreme constant temperatures, mean fecundity was much reduced; however, females at 21.1°C laid significantly more eggs ($p < 0.05$) than at 32.2°C. This phenomenon was also reported by Leppla et al. (1977) for *A. gemmatalis* and may be linked to a possible greater speed of degeneration of enzymes controlling insect fecundity at the higher constant temperature (see Barfield 1976).

Females originated from "laboratory" larvae reared on artificial diet had a significantly higher ($p < 0.05$) mean fecundity than females originated from "wild" larvae reared on leaves (pod fill stage) for the variable regime. Mean fecundity for "laboratory" females was not significantly different ($p > 0.05$) from constant temperatures of 23.9°, 29.4°C, and the field regime; whereas, "wild" females subjected to the variable temperature regime had a mean fecundity higher, but not significantly different ($p > 0.05$) from females subjected to constant 21.1°C.

Reasons for the significant difference observed for "laboratory" and "wild" females at the variable temperature regime can possible be explained by one of the two following alternatives: (1) "wild" insects were more "sensitive" to the artificial laboratory rearing conditions (cage size, handling, etc.) than "laboratory" insects; or (2) the particular laboratory cultured insects were selected through several generations for higher fecundity than wild insects. Greene et al. (1976)

gave evidence that apparently supports the first alternative. The authors compared insects fed on artificial diet (same used in the present study) and on soybean leaves for the fourth to tenth generation under laboratory conditions (temperature = $28^{\circ} \pm 2^{\circ}C$; humidity = 90 ± 5%) and found that *A. gemmatalis* females were similar for the two treatments. However, the authors studied fecundity for grouped females inside 30 x 30 x 45 cm Plexiglas® cages originated initially from "field" insects and, after colony establishment, only groups of the same colony were compared on artificial diet and on leaves. In the present study, fecundity was investigated in small wire screen cages for individual females from: (1) "laboratory" insects which had been reared under artificial conditions for 24 generations, and (2) "wild" insects which were obtained from field populations just before experimentation was begun. When "laboratory" cultured larvae were reared under caged conditions on soybean fields (late vegetative stage) and resulting female adults placed individually in small screen cages in a field insectary with recorded temperatures (see Table 28, Appendix) roughly fluctuating as in the variable chamber, mean fecundity was not significantly different ($p > 0.05$) from that of "laboratory" females subjected to the variable temperature regime. Therefore, when laboratory cultured insects were shifted from artificial to "more natural" conditions, mean fecundity was not significantly altered.

The above observations apparently support the second alternative. There is no basis to affirm that fecundity of "wild" insects would not be reduced if artificial conditions used in the present experiment were modified. Consequently, neither of the alternatives can be discarded due to the limited, and not readily comparable, data which seems to support one or the other alternative.

Mean percent egg hatch (Table 9) varied from 68.6 at 21.1°C to 85.71 at the variable temperature regime ("wild insects). Values for 21.1°C were significantly lower ($p < 0.05$) than for other constant temperatures or any other temperature regime. Values for the variable regime ("wild" insects) were highest but not significantly different ($p > 0.05$) from 26.7°C. Similar results occurred at 21.1°, 29.4°, 32.2°C, variable regime ("laboratory" insects), and field experiment. Results for constant temperatures in the 26.7° to 32.2°C range generally agree with Leppla et al. (1977) who found that *A. gemmatalis* egg hatch at 26.7° and 32.2°C was ca 85%. However, they reported that egg hatch at 21.1°C was "almost none," which is in disagreement with results found in the present study.

Mean longevity (Table 9) varied from 11.2 days for females at 32.2°C to 24.8 days for females at 21.1°C. As temperature increased, longevity decreased in the range of constant temperatures which is in agreement with the Leppla et al. (1977) studies on *A. gemmatalis* and is a "typical" response by insects to increasing temperatures as exemplified by Fye and McAda (1972), Ragusa (1974), Engroff and Watson (1975), Barfield et al. (1977b), and many others. Values agreed with Leppla et al. (1977), with the only difference occurring at 32.2°C (6.3 days as opposed to 11.2 days in the present study). Longevity of females at the variable temperature regime was similar to females at 29.4°C. Females at field conditions had a mean longevity comparable to 32.2°C but did not differ significantly ($p > 0.05$) from females at 29.4°C. Unmated females at 26.7°C lived significantly ($p < 0.05$) longer than mated females at the same temperature. This is in agreement with the review by Engelmann (1970) who showed that unmated insects usually live longer through resorption of infertile eggs as an energy source for increased longevity. Virgin *A. gemmatalis* females usually lay very few eggs when compared to mated females and could possibly resorb some of the eggs as a strategy for the sake of longer longevity. However, the existence of this mechanism has yet to be demonstrated for *A. gemmatalis*.

Net reproductive rate (Ro) of females for different environmental conditions is a useful population statistic which refers to the number of times a population will multiply per generation (Laughlin 1965), or, in other words, the average number of female offspring produced during a female's lifetime. Fertility tables are constructed (Tables 20 to 27, p. 119-126, Appendix) in order to obtain Ro which is necessary for the calculations of other important population statistics such as Tc (cohort generation time), rc (capacity for increase), and λ (finite capacity of increase). These three population statistics (Tc, rc, and λ) were not computed in the present woek because needed information on complete life cycle was not collected. The term fertility table as opposed to fecundity table is used in this work because the former term is more appropriate since it refers to live births (Southwood 1978). Net reproductive rate (Table 1) varied from 135.11 at 32.2°C to 369.00 at 26.7°C. Differences observed in magnitude of Ro for different treatments followed the same patterns as observed for mean fecundity values. Ro values presented by Leppla et al. (1977) differed from values obtained in the present work due to the lower mean fecundity observed at 21.1°, 26.7°, and 32.2°C, as opposed to high values presented in this work for the same range of temperatures.

Figures 8 and 9 show cumulative mean fecundity for constant temperatures and variable and field regimes, respectively. Females

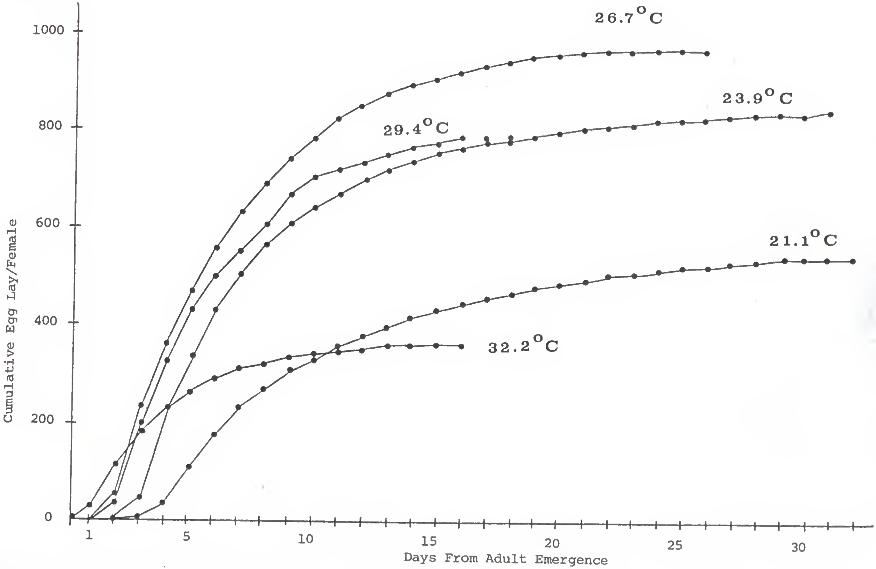


Figure 8. Cumulative egg lay per mated female at different constant temperatures. Photoperiod = 14L:10D; humidity >80%.

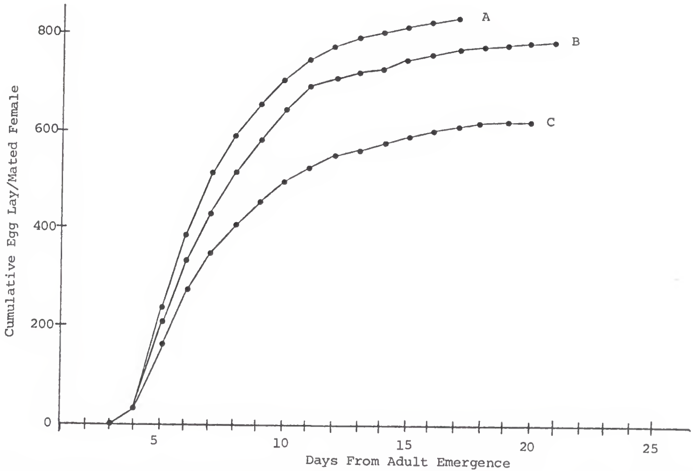
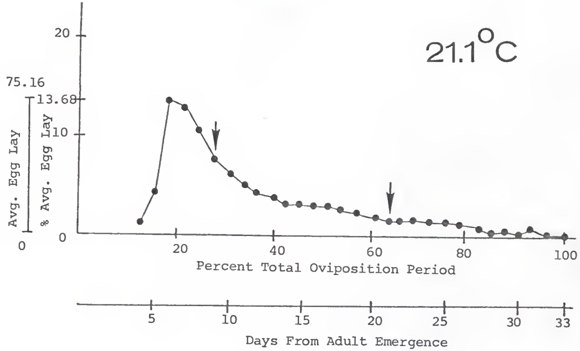


Figure 9. Cumulative egg lay per mated female resulted from larvae reared at a variable (laboratory) and field regime. A = Field regime--adults reared from larvae under caged conditions on late vegetative soybean stage; B = variable regime (oscillations ca between 22 and 34^{o}C)--adults resulted from "laboratory" larvae fed artificial media; and C = same as B--adults resulted from "wild" larvae fed soybean leaves (R_4 - R_5).

subjected to a constant temperature of 26.7°C had significantly higher cumulative mean fecundity ($p < 0.05$) than at any other constant temperature. Results were similar at 29.4° and 23.9°C, even though at 23.9°C females oviposited longer. At the three intermediate constant temperatures and 21.1°C cumulative mean fecundity increased sharply in the first 9 to 12 days post adult emergence; whereas, at 32.2°C this increase occurred in the first 5 to 6 days. This fact is in agreement with Barfield et al. (1977b) who studied effect of temperature on *Bracon mellitor* Say. Females originated from laboratory cultured larvae reared under caged conditions in a field of 'Bragg' soybean (late vegetative stage) had higher cumulative mean fecundity than "laboratory" and "wild" females housed under the variable temperature regime. However, results were not statistically different ($p > 0.05$) for females under "field" conditions and "laboratory" females under the variable regime.

Figure 10 depicts mean fecundity and percent mean fecundity in relation to days from adult emergence and percent of total oviposition period for all tempearture regimes. Arrows indicate day or percent of total oviposition period at which 50 and 90% of cumulative mean fecundity were reached for the different regimes. Actual values can be extracted or derived from Tables 20 to 27 (Appendix, p. 119-126). Peak mean fecundity was highest at 26.7°C (186.48 eggs/female) and lowest at 21.1°C (75.16 eggs/female) for the range of constant temperatures investigated. Highest overall value occurred for females subjected to "field" conditions (198.47 eggs/female). Even though females at 21.1°C had higher mean and cumulative fecundity than females at 32.2°C, females at the latter temperature had higher peak mean oviposition and mean percent egg lay and, therefore, laid most eggs



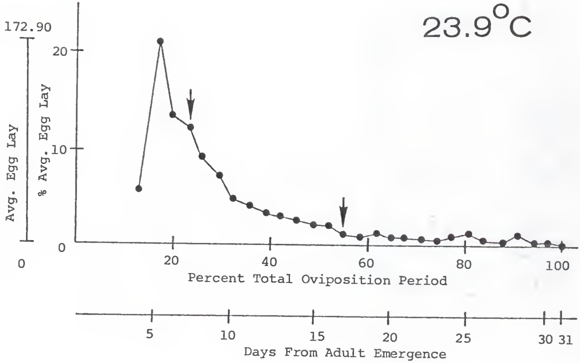
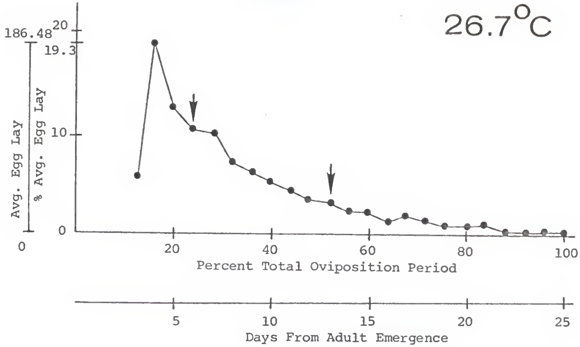
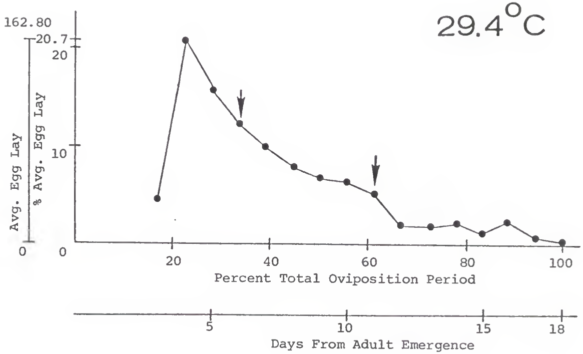


Figure 10. Average daily fecundity and percent average daily fecundity for females subjected to different temperature regimes. Arrows indicate 50 and 90% cumulative average fecundity.





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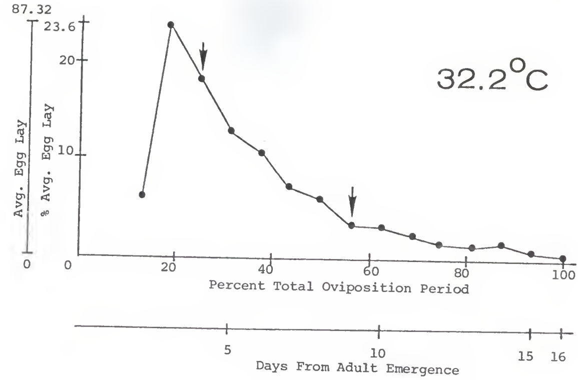

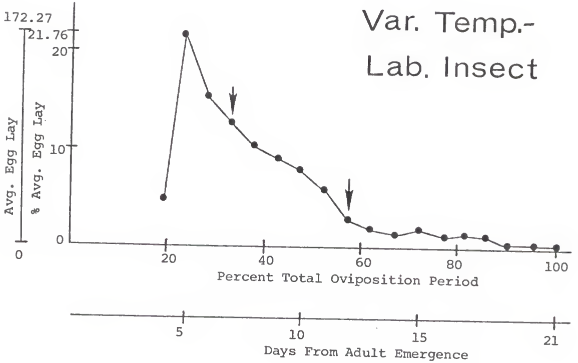

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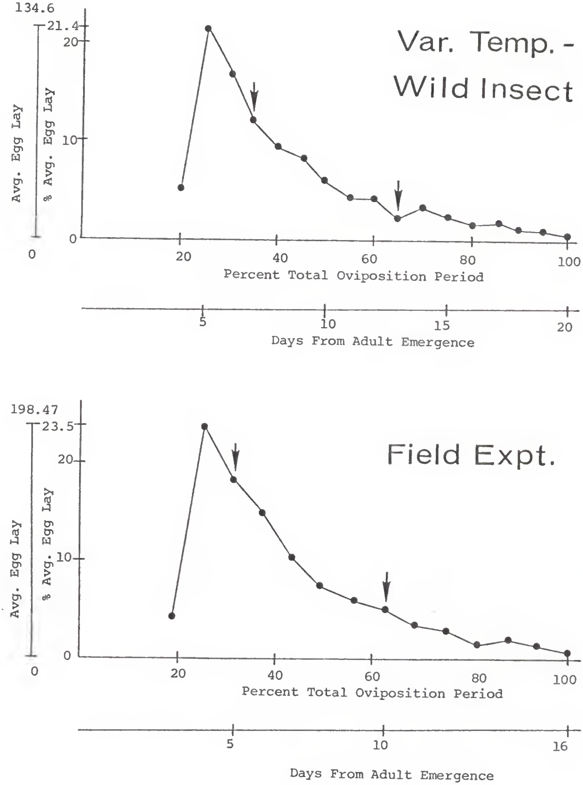

Figure 10--Continued.

earlier than at any other temperature regime. However, peak mean oviposition and percent egg lay for females at 32.2°C and those under "field" conditions were not substantially different. Total oviposition period varied from 16 days at 32.2°C and in the field experiment to 33 days at 21.1°C. Days to reach 50 and 90% of cumulative mean fecundity were 9, 7, 6, 6, 4, 7, 7, and 5, and 21, 17, 13, 11, 9, 12, 13, and 10 days, respectively, for females at 21.1°, 23.9°, 26.7°, 29.4°, 32.2°C, variable (laboratory insects), variable (wild insects), and field conditions. Peak mean fecundity occurred at early ages varying with temperature. Peaks occurred on days 6, 5, 4, 4, 3, 5, 5, and 4, respectively, for the above temperature regimes. Therefore, as temperature increased, females tended to lay most eggs earlier than at lower temperatures; however, in terms of percent of total oviposition period, there were no substantial differences in peak mean daily fecundity which occurred at ca 19 to 25% of the total oviposition period. The magnitude of peak percent average fecundity, however, was greater at high than at low temparatures, indicating that increased metabolic rate caused by higher temperatures induced females to lay eggs more rapidly and in a shorter time.

Average egg hatch for constant temperatures and variable and field regimes is given in Figures 11 and 12, respectively. For all temperature regimes, mean daily egg hatch was high initially but decreased with increased female age. For the constant temperatures, egg viability declined more rapidly at 32.2° and 29.4°C than at the other lower temperatures. Field experiment (average field temperature ca 29.0°C) results showed that daily egg hatch declined at a much faster relative rate than the "wild" and "laboratory" eggs under the variable

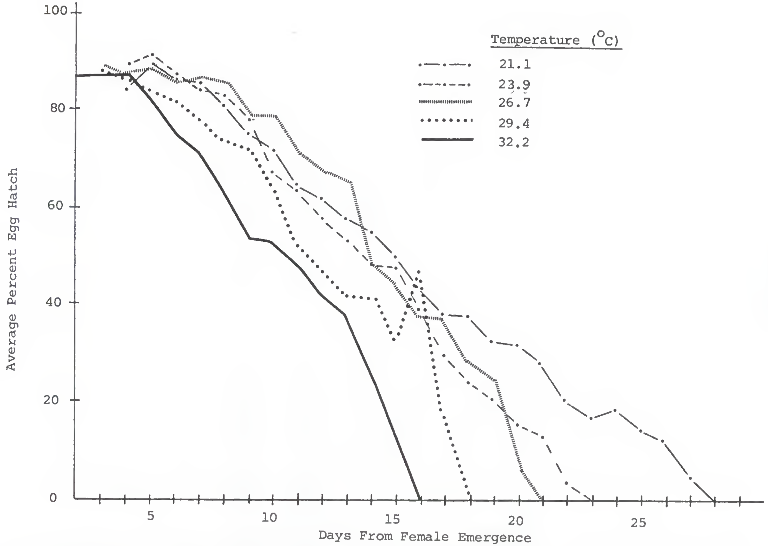

Figure 11. Average percent daily egg hatch for females subjected to different constant temperatures.

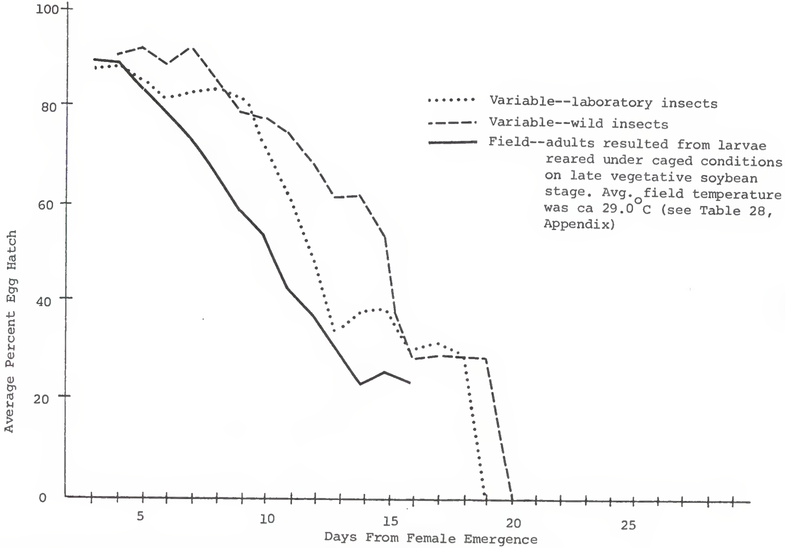

Figure 12. Average percent daily egg hatch for females subjected to a variable temperature regime (oscillation between 22 and 34°C) (wild and laboratory insects) and for females under field conditions.

temperature regime but similar to the 32.2°C constant temperature regime.

Cumulative percent mortalities for females housed under the different constant temperature and variable and field experiments are shown in Figures 13 and 14. For constant temperatures, results clearly show that 100% mortality was reached sooner as temperatures increased and the temperature effect on mortality was approximately linear in proportion to change in temperature. Leppla et al. (1977) presented data for *A. gemmatalis* adults at 21.1°, 26.7°, and 32.2°C which followed the same general trend found in the present work.

One of the interesting and important aspects found in the present research on *A. gemmatalis* was the much higher mean fecundity than had been reported by Greene et al. (1976) and Leppla et al. (1977). Greene et al. (1976) reported ca 180 eggs at 28° ± 2°C and Leppla et al. (1977) presented data showing that at 21.1°, 26.7°, and 32.2°C, ca 138, 402, and 37 eggs, respectively, were deposited during the lifetime of a mated female. However, these authors investigated fecundity of grouped females which may have reduced the maximum reproductive potential of *A. gemmatalis* adults. Other researchers have demonstrated that insects in isolation had higher fecundities that did those under more crowded conditions (Pearl 1932, Henneberry and Kishaba 1960, Engelmann 1970, Guerra et al. 1972). In the present studies, fecundity was investigated for isolated females, and fecundities were 3.5-, 2.1-, and 8.4-fold higher than values obtained by Leppla et al. (1977) at identical temperatures. Adverse conditions such as collisions, interference with feeding, resting, and pairing which may reduce fecundity of grouped adults under laboratory conditions (Engelmann 1970) are less likely to

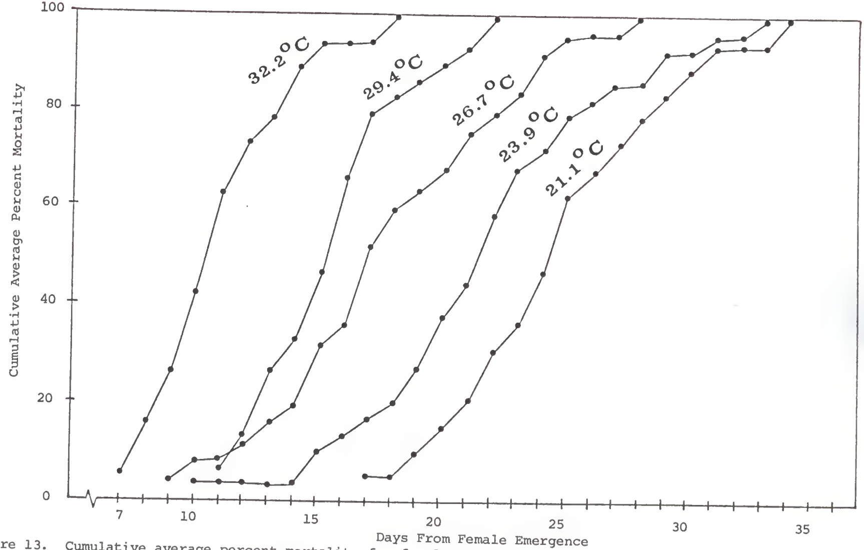

Figure 13. Cumulative average percent mortality for females subjected to different constant temperatures.

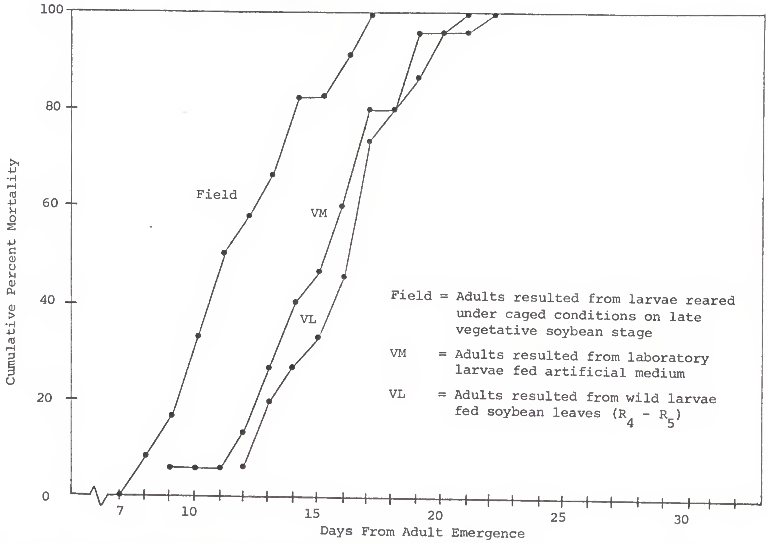

Figure 14. Cumulative average percent mortality for females subjected to a variable temperature regime (oscillations between 22 and 34°CO and field conditions (average field temperature ca 29.0°C).

occur under "normal" field conditions. Therefore, measured fecundity for individual females at different temperatures, in the present study, appears to be more realistic than reported previously for this species.

Results obtained in this study do not have the objective to mimic what would happen in a real ecosystem. Factors affecting insects under field conditions are complex and are interacting in different ways at any given time interval. However, controlled experiments such as those in the present research are necessary to explain isolated potential effects of some components of the ecosystem upon *A. gemmatalis*. Hopefully, these results will be of value to future researchers working with this insect and seeking a better understanding of factors affecting insects under natural conditions.

CONCLUSIONS

Present research provided useful and basic information on the effect of soybean phenology on consumption, development, and fecundity of *A. gemmatalis* as well as on the influence of different temperature regimes on fecundity of this insect. Both factors, plant stage and temperature, in conjunction with various other factors, act upon this insect to bring about population changes. Difficulties in attributing observed effects to specific factors under field conditions dictated that the effect of soybean phenological stage and temperatures upon this insect be investigated under controlled laboratory conditions. Results provide useful information on the potential effect of each factor on *A. gemmatalis*.

Plant-insect relationships, under field conditions, are dictated by a number of factors such as plant abundance, physical characteristics of leaves, leaf nutritive value, presence or absence of chemical stimulants or deterrents to insect feeding, as well as synchrony of insect and plant phenology and ovipositional habits of adult females. Effects of different plants or different phenological stages of a plant on insects are not separated easily in terms of quantity eaten and nutritional value of the food. Quantitative and qualitative analyses of insect growth and reproduction on food plants are necessary for a better understanding of the observed effects on insects. In the present study, only quantitative analyses were carried out to determine the effect of soybean growth stage on consumption, development, and fecundity of *A. gemmatalis*, but reference was made to the nutritive value of soybean leaves at different phenological stages, based on available literature. This type of information, although useful, does not allow a precise determination of cause-effect relationships because consumption, development, and reproduction have not been associated with specific nutrients or other plant factors. Very little information on this aspect is available in the literature due to the complexity involved in collecting and interpreting this type of data.

Anticarsia gemmatalis larvae consumed similar dry weight amounts of soybean leaves corresponding to successive soybean stages. Larvae consumed more fresh weight and resulting adults were more fecund when larvae fed on early rather than on late stages of soybean crop phenology. Fecundity was highest at early plant stages, apparently due to the high nutritional value of leaves in this phenological period.

Controlled experiments in the present research have shown that the realized fecundity of *A. gemmatalis* was much higher than previously reported for this species and varied substantially with changes in temperature. Fecundity was higher at 26.7°C than at any other temperature tested, and temperatures ranging from 23.9° to 29.4°C proved to be most favorable for this species. Fecundity was much lower at 21.1°C and 32.2°C. Females resulting from "laboratory" larvae subjected to a "square wave" regime simulating summer temperatures at Gainesville, Florida, (roughly, fluctuations between 22° and 34°C) were significantly more fecund than "wild" females resulting from larvae fed on leaves and subjected to the same variable regime. These differences were attributed to either: (1) greater sensitivity of "wild" insects to the artificial laboratory conditions; or (2) genetic differences between "laboratory" and "wild" insects. Adults resulting from "laboratory" larvae reared on caged soybean in the field had similar fecundity to "laboratory" females under the "square wave" regime. Longevity of females decreased as temperature increased. Mean egg hatch was significantly lower at 21.1°C than at any other constant or variable temperature. Mean daily egg hatch was shown to decrease with female age.

Results in the present research were obtained under controlled laboratory conditions and must be treated as indicative of potential effects on *A. gemmatalis* populations. Results are not intended to describe or predict precisely what would happen in the complex ecosystem of this insect. However, results obtained provide useful information which, hopefully, will be helpful to future workers seeking a better understanding of the population dynamics of *A. gemmatalis* in relation to a complex ecosystem.

If scientists are to derive viable Integrated Pest Manatement (IPM) strategies for *A. gemmatalis*, present results must be accompanied by research designed specifically to: (1) elucidate mechanisms initiating and controlling dispersal of *A. gemmatalis*; (2) determine the sequence of host plants utilized by *A. gemmatalis* before and after reaching soybean; (3) quantify the effect of intermediary host plants on development, survival, and reproduction of this species; (4) associate specific nutrients in successive soybean phenological stages with effects observed on the life history of this insect; (5) relate *A. gemmatalis* population dynamics to specific microhabitat (canopy environments), changes; and (6) better assess the role played by natural enemies, as well as factors regulating natural enemy abundance, on the soybean agroecosystem and how to best manipulate them in suppressing populations of *A. gemmatalis*.

APPENDIX

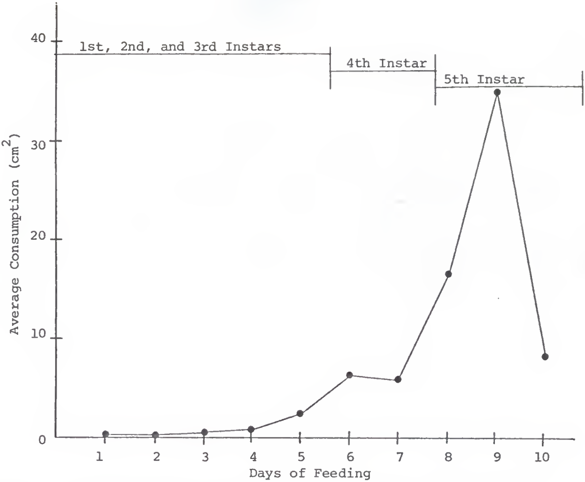

Figure 15. Daily leaf area consumption by *A. gemmatalis* larvae fed excised leaves from flowering soybean stage. Temperature = 26.7° ± 1°C; photoperiod = 14L:10D; humidity >80%.

Table 10. Average daily fresh weight consumption (grams ± SE) for *A. gemmatalis* larvae fed excised leaves from successive soybean phenological stages. Temperature = 26.7°C; photoperiod = 14L:10D; humidity >80%.

	Average Fresh Weight Consumed/Larva (grams ± SE)				
	Plant Stage				
Day	Early Veg.	Late Veg.	Flowering	Pod Set - Fill	Senescent
1	0.0029±0.0003	0.0037±0.0003	0.0050±0.0006	0.0049±0.0003	0.0020±0.0003
2	0.0035±0.0002	0.0030±0.0003	0.0069±0.0006	0.0042±0.0003	0.0031±0.0002
3	0.0068±0.0005	0.0117±0.0006	0.0075±0.0009	0.0088±0.0012	0.0056±0.0003
4	0.0105±0.0004	0.0153±0.0006	0.0140±0.0027	0.0116±0.0006	0.0147±0.0007
5	0.0290±0.0007	0.0273±0.0008	0.0356±0.0016	0.0235±0.0008	0.0214±0.0006
6	0.0385±0.0010	0.0798±0.0021	0.1056±0.0032	0.0565±0.0017	0.0597±0.0027
7	0.0899±0.0035	0.1304±0.0025	0.1009±0.0028	0.0804±0.0028	0.1256±0.0048
8	0.1372±0.0041	0.2547±0.0076	0.2150±0.0091	0.1181±0.0071	0.1408±0.0085
9	0.1756±0.0061	0.5631±0.0121	0.5157±0.0090	0.4015±0.0146	0.3846±0.0194
10	0.4003±0.0131	0.259 ±0.0209	0.157 ±0.0159	0.356 ±0.0143	0.3869±0.0252
11	0.4306±0.0241	0.047 ±0.0044	-	0.0725±0.0076	0.0802±0.0097
12	0.1179±0.0334	-	-	-	0.1396±0.1258

Table 11. Total fecundity per mated female resulting from larvae fed excised leaves from successive soybean phenological stages under laboratory conditions. Temperature = 26.7°C; photoperiod = 14L;10D; humidity > 80%.

	Total Number of Eggs				
	Plant Stage				
Female	Early Veg.	Late Veg.	Flowering	Pod Set - Fill	Senescent
1	741	1092	620	896	418
2	1356	551	893	1019	676
3	583	1066	914	770	453
4	1275	788	822	625	574
5	884	731	513	669	687
6	798	952	982	631	524
7	929	917	412	1049	435
8	981	659	676	860	635
9	1402	828	1163	664	535
10	954	1049	545	947	491
11	1197	1199	723	545	427
12	524	723	462	847	457
13	1075	936	852	861	450
14	1164	746	685	805	495
15	984	994	403	909	478
16	746	852	1064	1106	505
17	1131	1096	762	635	
18	749	1069	638	1070	
19	1171	1002	718	851	
20	673	887	898	746	
21	1088	877	878	721	
22	870	544	737		
23		503	491		
24		1161	932		
25		1238	657		
26		1086	721		
27		429	948		
28		1113	546		
29			1027		
30			956		
31			912		

Table 12. Average daily fecundity (± SE) of *A. gemmatalis* females resulted from larvae fed excised leaves from successive soybean phenological stages. Temperature = 26.7° ± 1°C; photoperiod = 14L:10D; humidity >80%.

	Average Fecundity/Mated Female (± SE)				
	Plant Stage				
Day	Early Veg.	Late Veg.	Flowering	Pod Set - Fill	Senescent
1	-	-	-	-	-
2	-	-	-	-	-
3	48.64*	40.89*	54.29*	29.14*	13.25*
4	248.09±16.15	220.71±13.53	226.32±10.87	238.09±9.76	135.19±9.51
5	208.73± 9.62	206.39±10.61	109.74± 9.88	182.62±7.40	104.00±4.14
6	157.41±12.67	157.85± 9.23	116.58± 8.47	126.86±8.14	72.25±3.44
7	104.23±10.72	91.61± 7.99	78.52± 6.73	84.90±6.61	60.19±5.05
8	70.27± 8.17	60.04± 7.21	50.45± 6.57	53.95±6.41	48.00±3.93
9	47.91± 6.58	47.63± 5.97	37.13± 5.14	39.95±5.78	30.87±4.40
10	34.82± 4.28	30.77± 5.14	23.87± 3.77	27.15±5.41	24.57±3.27
11	25.18± 3.66	29.87± 4.71	14.61± 3.02	20.00±5.10	21.77±4.66
12	17.14± 3.79	20.09± 4.27	8.64± 2.92	24.65±5.43	14.30±3.36
13	18.76± 4.18	19.81± 4.26	12.14± 3.05	10.57±2.77	14.87±3.23
14	15.69± 3.63	13.10± 2.88	8.26± 1.86	11.40±2.56	15.67±5.33
15	12.86± 3.67	9.67± 2.47	11.41± 3.24	15.44±8.32	10.80±4.41
16	10.30± 2.77	8.31± 2.86	10.73± 3.32	10.00±2.65	3.50±1.19
17	9.89± 3.33	8.82± 3.06	6.71± 2.01	6.00±1.09	4.00±2.00
18	11.67± 4.11	6.40± 2.70	7.93± 2.15	7.00±3.05	2.00
19	7.60± 3.04	6.00± 2.39	5.67± 1.42	5.25±2.59	1.00
20	4.00± 1.64	3.57± 1.49	4.70± 1.55	5.25±3.27	1.00
21	8.00± 6.00	3.00± 1.47	4.71± 1.63	2.50±1.19	0.00
22	3.00	2.50± 1.26	2.33± 1.11	1.50±0.64	3.00
23	3.00	1.00± 0.58	3.25± 0.94	1.50±0.50	
24		0.00	2.75± 1.03	1.00±0.00	
25		0.00	2.67± 1.20	1.00±1.00	
26		0.00	3.00± 1.00	0.00	
27		0.00	2.00± 2.00		
28		0.00	0.00		

* Average number of eggs on mating cage walls before females were separated.

Table 13. Fertility table for *A. gemmatalis* females resulted from larvae fed early vegetative stage soybean leaves. Temperature = 26.7° ± 1°C; photoperiod = 14L:10D; humidity >80%.

x[a]	lx[b]	mx[c]	mx'[d]	lx'[e]	mx''[f]	lx'mx''
1	22	0	0	1	0	0
2	22	0	0	1	0	0
3	22	48.64	39.67	1	19.83	19.83
4	22	248.09	214.82	1	107.41	107.41
5	22	208.73	184.10	1	92.05	92.05
6	22	157.41	133.41	1	66.70	66.70
7	22	104.23	79.14	1	39.57	39.57
8	22	70.27	38.82	1	19.41	19.41
9	22	70.27	38.82	1	19.41	19.41
10	22	34.82	7.96	1	3.98	3.98
11	22	25.18	3.77	1	1.88	1.88
12	22	17.14	2.28	1	1.14	1.14
13	17	18.76	3.59	0.77	1.79	1.38
14	16	15.69	2.01	0.73	1.00	0.73
15	14	12.86	0.71	0.64	0.35	0.22
16	10	10.30	0.30	0.45	0.15	0.07
17	9	9.89	0.22	0.41	0.11	0.04
18	6	11.67	0.00	0.27	0.00	0.00
19	5	7.60	0.00	0.23	0.00	0.00
20	5	4.00	0.00	0.23	0.00	0.00
21	2	8.00	0.00	0.09	0.00	0.00
22	1	3.00	0.00	0.04	0.00	0.00
23	1	3.00	0.00	0.04	0.00	0.00
24	0	0.00	0.00	0.00	0.00	0.00

Σ lx'mx'' = 364.82

[a] age interval (days)

[b] age specific survivorship

[c] age specific fecundity

[d] age specific fertility

[e] age specific survivorship rate

[f] age specific fertility/2 (assuming 1:1 sex ratio)

Table 14. Fertility table for *A. gemmatalis* females resulted from larvae fed late vegetative soybean leaves. Temperature = 26.7° ± 1°C; photoperiod = 14L:10D; humidity >80%.

x[a]	lx[b]	mx[c]	mx'[d]	lx'[e]	mx''[f]	lx'mx''
1	28	0	0	1	0	0
2	28	0	0	1	0	0
3	28	40.89	34.28	1	17.14	17.14
4	28	220.71	197.60	1	98.80	98.80
5	28	206.39	181.35	1	90.67	90.67
6	28	157.86	133.51	1	66.75	66.75
7	28	91.61	64.61	1	32.30	32.30
8	28	60.04	34.54	1	17.27	17.27
9	27	47.63	20.59	0.96	10.29	9.88
10	26	30.77	11.54	0.93	5.77	5.37
11	24	29.87	8.58	0.86	4.29	3.69
12	23	20.09	5.31	0.82	2.65	2.17
13	21	19.81	3.81	0.75	1.90	1.42
14	19	13.10	1.57	0.68	0.78	0.53
15	15	9.67	0.27	0.54	0.13	0.07
16	13	8.31	0.39	0.46	0.19	0.07
17	11	8.82	0.19	0.39	0.09	0.02
18	10	6.40	0.00	0.36	0	0
19	9	6.00	0.00	0.32	0	0
20	7	3.57	0.00	0.25	0	0
21	4	3.00	0.00	0.14	0	0
22	4	2.50	0.00	0.14	0	0
23	3	1.00	0.00	0.11	0	0
24	3	0	0.00	0.11	0	0
25	3	0	0.00	0.11	0	0
26	3	0	0.00	0.11	0	0
27	3	0	0.00	0.11	0	0
28	2	0	0.00	0.11	0	0
29	2	0	0.00	0.07	0	0
30	0	0	0.00	0.07	0	0
31				0.00		

Σ lx'mx'' = 346.15

[a] age interval (days)
[b] age specific survivorship
[c] age specific fecundity
[d] age specific fertility
[e] age specific survivorship rate
[f] age specific fertility/2 (assuming 1:1 sex ratio)

Table 15. Fertility table for *A. gemmatalis* females resulted from larvae fed flowering stage soybean leaves. Temperature = 26.7° ± 1°C; photoperiod = 14L:10D; humidity >80%.

x[a]	lx[b]	mx[c]	mx'[d]	lx'[e]	mx''[f]	lx'mx''
1	31	0	0	1	0	0
2	31	0	0	1	0	0
3	31	54.29	49.13	1	24.56	24.56
4	31	226.32	202.83	1	101.41	101.41
5	31	169.74	151.00	1	75.50	75.50
6	31	116.58	94.33	1	47.16	47.16
7	31	78.52	53.33	1	26.66	26.66
8	31	50.45	27.75	1	13.87	13.87
9	31	37.13	14.75	1	7.37	7.37
10	30	23.87	6.71	0.97	3.35	3.25
11	28	14.61	3.37	0.90	1.68	1.52
12	25	8.64	1.88	0.81	0.94	0.76
13	21	12.14	2.52	0.68	1.26	0.86
14	19	8.26	1.26	0.61	0.63	0.38
15	17	11.41	0.59	0.55	0.29	0.16
16	15	10.73	1.53	0.48	0.76	0.37
17	14	6.71	0.14	0.45	0.07	0.03
18	13	7.92	0.38	0.42	0.19	0.08
19	12	5.67	0.67	0.39	0.33	0.13
20	10	4.70	1.00	0.32	0.50	0.16
21	7	4.71	0.00	0.23	0	0
22	6	2.33	0	0.19	0	0
23	4	3.25	0	0.13	0	0
24	4	2.75	0	0.13	0	0
25	3	2.67	0	0.10	0	0
26	2	3.00	0	0.06	0	0
27	2	2.00	0	0.06	0	0
28	1	0.00	0	0.03	0	0
29	1	0.00	0	0.03	0	0
30	0	0	0	0	0	0

Σ lx'mx'' = 304.23 = Ro

[a] age interval (days)
[b] age specific survivorship
[c] age specific fecundity
[d] age specific fertility
[e] age specific survivorship rate
[f] age specific fertility/2 (assuming 1:1 sex ratio)

Table 16. Fertility table for *A. gemmatalis* females resulted from larvae fed pod set - pod fill stage soybean leaves. Temperature = 26.7° ± 1°C; photoperiod = 14L:10D; humidity >80%.

x^a	lx^b	mx^c	mx'^d	lx'^e	mx''^f	$lx'mx''$
1	21	0	0	1	0	0
2	21	0	0	1	0	0
3	21	29.14	26.14	1	13.07	13.07
4	21	238.09	218.85	1	109.42	109.42
5	21	182.62	164.06	1	82.03	82.03
6	21	126.86	111.20	1	55.60	55.60
7	21	84.90	63.00	1	31.50	31.50
8	21	53.95	33.19	1	16.59	16.59
9	21	39.95	20.66	1	10.33	10.33
10	20	27.15	9.15	0.95	4.57	4.35
11	19	20.00	5.79	0.90	2.89	2.60
12	17	24.64	8.40	0.81	4.20	3.40
13	14	10.57	2.07	0.67	1.03	0.69
14	10	11.40	0.50	0.48	0.25	0.11
15	9	15.44	1.00	0.43	0.50	0.21
16	8	10.00	1.00	0.38	0.50	0.19
17	7	6.00	0.72	0.33	0.36	0.12
18	6	7.00	0.16	0.29	0.08	0.02
19	4	5.25	0	0.09	0	0
20	4	5.25	0	0.19	0	0
21	4	2.50	0	0.19	0	0
22	4	1.50	0	0.19	0	0
23	2	1.50	0	0.09	0	0
24	2	1.00	0	0.09	0	0
25	2	1.00	0	0.09	0	0
26	2	0	0	0.09	0	0
27	0	0	0	0	0	0

$\Sigma\ lx'mx'' = 330.23 = Ro$

[a] age interval (days)
[b] age specific survivorship
[c] age specific fecundity
[d] age specific fertility
[e] age specific survivorship rate
[f] age specific fertility/2 (assuming 1:1 sex ratio)

Table 17. Fertility table for *A. gemmatalis* females resulted from larvae fed senescent stage soybean leaves. Temperature = 26.7° ± 1°C; photoperiod 14L:10D; humidity >80%.

x[a]	lx[b]	mx[c]	mx'[d]	lx'[e]	mx''[f]	lx'mx''
1	16	0	0	1	0	0
2	16	0	0	1	0	0
3	16	13.25	12.00	1	6.00	6.00
4	16	135.19	126.38	1	63.19	63.19
5	16	104.00	91.56	1	45.78	45.78
6	16	72.25	58.88	1	29.44	29.44
7	16	60.19	43.51	1	21.75	21.75
8	16	48.00	31.13	1	15.56	15.56
9	15	30.87	14.87	0.94	7.43	6.99
10	14	24.57	10.36	0.87	5.18	4.51
11	13	21.77	7.47	0.81	3.73	3.02
12	10	14.30	3.30	0.62	1.65	1.02
13	8	14.87	3.75	0.50	1.87	0.94
14	6	15.67	3.00	0.37	1.50	0.55
15	5	10.80	2.40	0.31	1.20	0.37
16	4	3.50	0.75	0.25	0.37	0.09
17	2	4.00	0.50	0.12	0.25	0.03
18	1	2.00	0	0.06	0	0
19	1	1.00	0	0.06	0	0
20	1	1.00	0	0.06	0	0
21	1	0	0	0.06	0	0
22	0	0	0	0	0	0

Σ lx'mx'' = 199.24 = Ro

[a] age interval (days)
[b] age specific survivorship
[c] age specific fecundity
[d] age specific fertility
[e] age specific survivorship rate
[f] age specific fertility/2 (assuming 1:1 sex ratio)

Table 18. Total fecundity per individual female reared from eggs at different temperature regimes. Photoperiod = 14L:10D; humidity >80% except for field experiment.

	Total Number of Eggs							
	Temperature (°C)							
Female	21.1	23.9	26.7	29.4	32.2	Var. A[a]	Var. B.[b]	Field[c]
1	353	916	1048	668	271	777	438	1018
2	495	510	840	792	229	694	611	699
3	573	576	1083	822	420	635	502	704
4	640	730	880	878	212	648	470	822
5	494	619	571	571	417	694	706	661
6	433	462	799	530	423	641	579	706
7	407	796	965	728	238	836	521	572
8	378	474	931	779	316	863	489	985
9	481	789	843	632	301	407	467	661
10	618	837	828	681	249	541	532	603
11	366	598	787	828	283	918	608	596
12	646	688	940	730	296	392	412	567
13	557	826	857	726	324	646	621	
14	337	667	618	800	281	892	768	
15	349	919	867	537	340	843	661	
16	636	800	861		349			
17	528	792	963		376			
18	420	716	920		265			
19	463	751	817		301			
20		793	649					
21		885	804					
22		863	866					
23		692	978					
24		810	619					
25		781	720					
26		751						
27		645						
28		818						
29		733						

[a] Average temperatures during "summer" at Gainesville, Florida (roughly, fluctuation between 22° and 34°C - "laboratory" insects

[b] same as above - "wild" insects

[c] "laboratory" insects under field conditions. Temperatures recorded by a hygorthermograph (see table 28).

Table 19. Average daily fecundity (± SE) of *A. gemmatalis* females reared from eggs at different temperature regimes.

	Average Fecundity/Mated Female (± SE)							
	Temperature (°C)							
Day	21.1	23.9	26.7	29.4	32.2	Variable A[a]	Variable B[b]	Field Temp.
1	-	-	-	-	-	-	-	-
2	-	-	-	-	22.37	-	-	-
3	-	-	53.40	36.27	87.32± 3.86	-	-	-
4	6.68	48.28	186.48±7.47	162.80±10.08	66.95±3.91	37.33	32.67	195.33±19.03
5	24.21	172.90±6.78	125.64±7.13	125.00±10.96	48.10±3.04	172.37±13.19	134.60±15.10	152.42± 6.27
6	75.16±4.77	111.76±6.36	105.64±7.13	96.80± 7.50	40.05±3.75	121.60± 7.18	105.13± 6.82	126.42±10.37
7	71.37±4.81	99.31±4.23	96.88±5.57	77.87± 8.88	27.17±2.55	100.07± 6.28	75.93± 3.67	85.75± 5.04
8	58.58±3.43	77.07±3.85	69.52±4.26	61.93± 6.43	22.06±3.11	79.40± 6.84	59.07± 7.47	60.73± 3.32
9	41.79±3.60	57.14±4.11	58.33±4.54	54.07± 4.22	12.86±1.31	72.86± 5.77	50.40± 5.41	48.50± 6.76
10	33.42±3.13	40.25±2.59	52.30±3.30	50.20± 4.92	12.00±1.93	61.57± 6.06	37.47± 4.69	41.37± 6.53
11	27.89±2.29	32.93±2.68	41.26±2.87	39.64± 5.76	9.14±1.49	45.43± 5.42	27.80± 2.99	27.83± 5.46
12	24.26±1.75	28.96±2.25	33.77±2.91	15.23± 3.12	6.00±1.70	21.85± 3.80	26.57± 4.95	22.60± 4.02
13	20.26±1.64	26.46±2.28	30.71±3.18	14.73± 3.11	4.50±1.04	16.09± 3.40	12.75± 3.03	12.00± 4.02
14	17.89±1.98	23.00±2.13	22.65±3.16	16.30± 3.37	6.50±3.50	11.00± 2.72	19.64± 3.54	16.50± 1.50
15	18.53±1.81	18.11±1.99	19.53±2.34	10.12± 3.72	3.00	14.00± 3.03	14.40± 2.60	11.00± 1.00
16	17.26±1.77	15.92±1.89	13.62±1.73	18.20± 3.81	2.00	11.33± 3.52	8.87± 1.93	8.00
17	17.33±2.20	11.54±1.54	15.50±2.62	6.67± 2.96	0.00	11.33± 5.46	10.50± 3.33	
18	14.11±1.36	7.83±1.07	12.20±3.44	1.00± 1.00		9.67± 6.17	6.33± 3.33	
19	11.06±1.44	9.47±1.56	8.00±2.31	0.00		3.00	5.00± 1.00	
20	9.50±1.71	6.55±1.03	5.50±2.80			1.00	2.00	
21	8.53±1.09	4.69±0.94	8.50±2.59			2.00		
22	9.15±1.50	5.75±1.39	2.80±1.74					
23	8.67±1.73	4.44±1.21	0.50±0.50					
24	7.00±1.37	7.00±2.18	0.50±0.50					
25	7.14±1.14	6.17±2.70	1.00					
26	5.83±1.64	1.20±1.20	0.00					
27	3.60±1.17	0.50±0.50	0.00					
28	1.75±0.75	7.50±4.84						

Table 19.--continued.

29	2.33 0.33	1.50 1.50
30	2.00 0.00	1.00 1.00
31	3.00	2.00
32	0.00	0.00
33	1.00	

[a] Regime simulating average temperatures during "summer" at Gainesville, Florida (roughly, fluctuations between 22 and 34°C)--laboratory insects.

[b] Same as above--wild insects.

Table 20. Fertility table for *A. gemmatalis* females reared from eggs at a constant temperature of 21.1° ± 1°C. Photoperiod = 14L: 10D; humidity >80%.

x^{a}	lx^{b}	mx^{c}	mx'^{d}	lx'^{e}	mx''^{f}	$lx'mx''$
1	19	0	0	1	0	0
2	19	0	0	1	0	0
3	19	0	0	1	0	0
4	19	6.68	6.00	1	3.00	3.00
5	19	24.21	21.68	1	10.84	10.84
6	19	75.16	65.72	1	32.86	32.86
7	19	71.37	61.48	1	30.74	30.74
8	19	58.58	47.90	1	23.95	23.95
9	19	41.79	32.32	1	16.16	16.16
10	19	33.42	24.95	1	12.47	12.47
11	19	27.89	18.89	1	9.44	9.44
12	19	24.26	15.63	1	7.81	7.81
13	19	20.26	12.05	1	6.02	6.02
14	19	17.89	10.47	1	5.23	5.23
15	19	18.53	9.74	1	4.87	4.87
16	19	17.26	8.16	1	4.08	4.08
17	18	17.33	7.16	0.95	3.58	3.40
18	18	14.11	5.56	0.95	2.78	2.64
19	17	11.06	3.71	0.89	1.85	1.65
20	16	9.50	3.13	0.84	1.85	1.65
21	15	8.53	2.53	0.79	1.26	0.99
22	13	9.15	2.23	0.68	1.11	0.75
23	12	8.67	2.00	0.63	1.00	0.63
24	10	7.00	1.60	0.53	0.80	0.42
25	7	7.14	1.14	0.37	0.57	0.21
26	6	5.83	1.00	0.32	0.50	0.16
27	5	3.60	0.40	0.26	0.20	0.05
28	4	1.75	0.00	0.21	0.00	0.00
29	3	2.33	0.00	0.16	0.00	0.00
30	2	2.00	0.00	0.10	0.00	0.00
31	1	3.00	0.00	0.05	0.00	0.00
32	1	0.00	0.00	0.05	0.00	0.00
33	1	1.00	0.00	0.05	0.00	0.00
34	0	0.00	0.00	0.00	0.00	0.00

$\Sigma lx'm'' = 179.68 = Ro$

a = age interval (days)
b = age specific survivorship
c = age specific fecundity
d = age specific fertility
e = rate of age specific survivorship
f = age specific fertility/2 - assuming 1:1 sex ratio

Table 21. Fertility table for *A. gemmatalis* females reared from eggs at a constant temperature of 23.9° ± 1°C. Photoperiod = 14L:10D; humidity >80%.

x[a]	lx[b]	mx[c]	mx'[d]	lx'[e]	mx''[f]	lx'mx''
1	29	0	0	1	0	0
2	29	0	0	1	0	0
3	29	0	0	1	0	0
4	29	48.28	42.66	1	21.33	21.33
5	29	172.90	158.76	1	79.38	79.38
6	29	111.76	98.17	1	49.08	49.08
7	29	99.31	83.69	1	41.84	41.84
8	29	77.07	64.62	1	32.31	32.31
9	29	57.14	46.45	1	23.22	23.22
10	28	40.25	27.89	0.96	13.94	13.39
11	28	32.93	22.15	0.96	11.07	10.63
12	28	28.96	17.64	0.96	8.82	8.47
13	28	26.46	15.53	0.96	7.76	7.45
14	28	23.00	12.00	0.96	6.00	5.76
15	26	18.11	9.34	0.90	4.67	4.20
16	25	15.92	7.28	0.86	3.64	3.13
17	24	11.54	4.33	0.83	2.16	1.80
18	23	7.83	2.14	0.79	1.07	0.84
19	21	9.48	2.58	0.72	1.29	0.93
20	18	6.55	1.05	0.62	0.52	0.32
21	16	4.68	0.87	0.55	0.43	0.24
22	12	5.75	0.42	0.41	0.21	0.09
23	9	4.44	0.00	0.31	0.00	0.00
24	8	7.00	0.00	0.28	0.00	0.00
25	6	6.17	0.00	0.21	0.00	0.00
26	5	1.20	0.00	0.17	0.00	0.00
27	4	0.50	0.00	0.14	0.00	0.00
28	4	7.50	0.00	0.14	0.00	0.00
29	2	1.50	0.00	0.07	0.00	0.00
30	2	1.00	0.00	0.07	0.00	0.00
31	1	2.00	0.00	0.03	0.00	0.00
32	1	0.00	0.00	0.03	0.00	
33	0			0.00		

Σ lx'mx'' = 304.41 = Ro

[a] age interval (days)

[b] age specific survivorship

[c] age specific fecundity

[d] age specific fertility

[e] age specific survivorship rate

[f] age specific fertility/2 (assuming 1:1 sex ratio)

Table 22. Fertility table for *A. gemmatalis* females reared from eggs at a constant temperature of 26.7° ± 1°C. Photoperiod = 14L:10D; humidity >80%.

x[a]	lx[b]	mx[c]	mx'[d]	lx'[e]	mx''[f]	lx'mx''
1	25	0	0	1	0	
2	25	0	0	1	0	
3	25	53.40	47.28	1	23.64	23.64
4	25	186.48	165.96	1	82.98	82.98
5	25	125.64	112.20	1	56.10	56.10
6	25	105.20	91.16	1	45.58	45.58
7	25	96.88	84.12	1	42.06	42.06
8	25	69.52	59.88	1	29.94	29.94
9	24	58.33	47.16	0.96	23.58	22.64
10	23	52.30	41.69	0.92	20.84	19.18
11	23	41.26	29.83	0.92	14.91	13.72
12	22	33.77	23.54	0.88	11.77	10.36
13	21	30.71	21.47	0.84	10.73	9.02
14	20	22.65	12.80	0.80	6.40	5.12
15	17	19.23	9.84	0.68	4.92	3.34
16	16	13.62	5.75	0.64	2.87	1.84
17	12	15.50	7.17	0.48	3.58	1.72
18	10	12.20	5.40	0.40	2.70	1.08
19	9	8.00	2.56	0.36	1.28	0.46
20	8	5.50	1.13	0.32	0.56	0.18
21	6	8.50	0.33	0.24	0.16	0.04
22	5	2.80	0.00	0.20	0.00	0.00
23	4	0.50	0	0.16	0	0
24	2	0.50	0	0.08	0	0
25	1	1.00	0	0.04	0	0
26	1	0.00	0	0.04	0	0
27	1	0.00	0	0.04	0	0
28	0			0.00		

Σ lx'mx'' = 369.0 = Ro

[a] age interval (days)

[b] age specific survivorship

[c] age specific fecundity

[d] age specific fertility

[e] age specific survivorship rate

[f] age specific fertility/2 (assuming 1:1 sex ratio)

Table 23. Fertility table for *A. gemmatalis* females reared from eggs at a constant temperature of 29.4° ± 1°C. Photoperiod = 14L:10D; humidity >80%.

x[a]	lx[b]	mx[c]	mx'[d]	lx'[e]	mx''[f]	lx'mx''
1	15	0	0	1	0	
2	15	0	0	1	0	
3	15	36.27	32.47	1	16.23	16.23
4	15	162.80	142.40	1	71.20	71.20
5	15	125.00	105.67	1	52.83	52.83
6	15	96.80	80.60	1	40.30	40.30
7	15	77.87	63.14	1	31.57	31.57
8	15	61.93	48.13	1	24.06	24.06
9	15	54.07	40.67	1	20.33	20.33
10	15	50.20	34.07	1	17.03	17.03
11	14	39.64	24.21	0.93	12.10	11.26
12	13	15.23	7.62	0.87	3.81	3.31
13	11	14.73	6.64	0.73	3.32	2.42
14	10	16.30	6.70	0.67	3.35	2.24
15	8	10.12	4.00	0.53	2.00	1.06
16	5	18.20	8.40	0.33	4.20	1.39
17	3	6.67	1.67	0.20	0.83	0.17
18	2	1.00	0.00	0.13	0.00	0.00
19	1	0	0	0.07	0	0
20	0	0	0	0	0	0

Σ lx'mx'' = 295.40

[a] age interval (days)

[b] age specific survivorship

[c] age specific fecundity

[d] age specific fertility

[e] age specific survivorship rate

[f] age specific fertility/2 (assuming 1:1 sex ratio)

Table 24. Fertility table for *A. gemmatalis* females reared from eggs at a constant temperature of 32.2 ± 1 °C. Photoperiod = 14L:10D; humidity >80%.

x[a]	lx[b]	mx[c]	mx'[d]	lx'[e]	mx''[f]	lx'mx''
1	19	0	0	1	0	0
2	19	22.37	19.58	1	9.79	9.79
3	19	87.32	76.73	1	38.36	38.36
4	19	66.95	58.79	1	29.39	29.39
5	19	48.10	40.05	1	20.02	20.02
6	19	40.05	31.10	1	15.55	15.55
7	18	27.17	19.95	0.95	9.97	9.48
8	16	22.06	15.06	0.84	7.53	6.32
9	14	12.86	7.29	0.74	3.64	2.70
10	11	12.00	6.64	0.58	3.32	1.92
11	7	9.14	4.71	0.37	2.35	0.87
12	5	6.00	3.00	0.26	1.50	0.39
13	4	4.50	1.75	0.21	0.87	0.18
14	2	6.50	2.50	0.10	1.25	0.12
15	1	3.00	1.00	0.05	0.50	0.02
16	1	2.00	0.00	0.05	0.00	0.00
17	1	0	0	0.05	0	0
18	0	0	0	0	0	0

Σ lx'mx'' = 369.0 = Ro

[a] age interval (days)

[b] age specific survivorship

[c] age specific fecundity

[d] age specific fertility

[e] age specific survivorship rate

[f] age specific fertility (assuming 1:1 sex ratio)

Table 25. Fertility table for *A. gemmatalis* females resulted from "laboratory" larvae fed artificial diet and subjected to a variable[a] temperature regime. Photoperiod = 14L:10D; humidity >80%.

x[b]	lx[c]	mx[d]	mx'[e]	lx'[f]	mx''[g]	lx'mx''
1	15	0	0	1	0	0
2	15	0	0	1	0	0
3	15	0	0	1	0	0
4	15	37.33	33.40	1	16.70	16.70
5	15	172.27	148.67	1	74.33	74.33
6	15	121.60	100.87	1	50.43	50.43
7	15	100.07	83.67	1	41.83	41.83
8	15	79.40	67.20	1	33.60	33.60
9	14	72.86	60.65	0.93	30.32	28.20
10	14	61.57	48.43	0.93	24.21	22.52
11	14	45.43	33.50	0.93	16.75	15.58
12	13	21.85	12.93	0.87	6.46	5.62
13	11	16.09	8.18	0.73	4.09	2.99
14	9	11.00	6.11	0.60	3.05	1.83
15	8	14.00	7.25	0.53	3.62	1.92
16	6	11.33	5.16	0.40	2.58	1.03
17	3	11.33	6.00	0.20	3.00	0.60
18	3	9.67	4.67	0.20	2.33	0.47
19	1	3.00	0	0.07	0	0
20	1	1.00	0	0.07	0	0
21	1	2.00	0	0.07	0	0
22	0	0	0	0	0	0

Σ lx'mx'' = 297.65 = Ro

[a] regime simulating average temperatures during "summer" at Gainesville, Florida (roughly, fluctuations between 34° and 22°C).

[b] age interval (days)

[c] age specific survivorship

[d] age specific fecundity

[e] age specific fertility

[f] age specific survivorship rate

[g] age specific fertility/2 (assuming 1:1 sex ratio)

Table 26. Fertility table for *A. gemmatalis* females resulted from "wild" larvae fed on soybean leaves and subjected to a variable[a] temperature regime. Photoperiod = 14L:10D; humidity >80%.

x[b]	lx[c]	mx[d]	mx'[e]	lx'[f]	mx''[g]	lx'mx''
1	15	0	0	1	0	0
2	15	0	0	1	0	0
3	15	0	0	1	0	0
4	15	32.67	29.60	1	14.80	14.80
5	15	134.60	123.80	1	61.90	61.90
6	15	105.13	95.26	1	47.63	47.63
7	15	75.93	69.93	1	34.96	34.96
8	15	59.07	52.27	1	26.13	26.13
9	15	50.40	41.13	1	20.56	20.56
10	15	37.47	30.60	1	15.30	15.30
11	15	27.80	21.40	1	10.70	10.70
12	14	26.56	19.86	0.93	9.93	9.23
13	12	12.75	8.00	0.80	4.00	3.20
14	11	19.64	14.19	0.73	7.09	5.18
15	10	14.40	9.10	0.67	4.55	3.05
16	8	8.87	3.62	0.53	1.81	0.96
17	4	10.50	4.25	0.27	2.12	0.57
18	3	6.33	2.66	0.20	1.33	0.27
19	2	5.00	1.50	0.13	0.75	0.10
20	1	2.00	0	0.07	0	0
21	0	0	0	0	0	0

Σ lx'mx'' = 254.54 = Ro

[a] regime simulating average temperatures during "summer" at Gainesville, Florida (Roughly, fluctuations between 34° and 22°C)

[b] age interval (days)

[c] age specific survivorship

[d] age specific fecundity

[e] age specific fertility

[f] age specific survivorship rate

[g] age specific fertility/2 (assuming 1:1 sex ratio)

Table 27. Fertility table for *A. gemmatalis* females reared from "laboratory" larvae under field conditions.[a]

x[b]	lx[c]	mx[d]	mx'[e]	lx'[f]	mx''[g]	lx'mx''
1	12	0	0	1	0	0
2	12	0	0	1	0	0
3	12	34.42	30.84	1	15.42	15.42
4	12	195.33	176.66	1	88.33	88.33
5	12	152.42	128.75	1	64.37	64.37
6	12	126.42	103.17	1	51.58	51.58
7	12	85.75	64.08	1	32.04	32.04
8	11	60.73	41.19	0.92	20.59	18.95
9	10	48.50	30.80	0.83	15.40	12.78
10	8	41.37	25.12	0.67	12.56	8.41
11	6	27.83	13.50	0.50	6.75	3.37
12	5	22.60	8.80	0.42	4.40	1.85
13	4	12.00	3.50	0.33	1.75	0.58
14	2	16.50	4.00	0.17	2.00	0.34
15	2	11.00	3.00	0.17	1.50	0.25
16	1	8.00	2.00	0.08	1.00	0.08
17	0	0	0	0	0	0

Σ lx'mx'' = 298.35 = Ro

[a] temperatures monitored daily (see table 28, Appendix)

[b] age interval

[c] age specific survivorship

[d] age specific fecundity

[e] age specific fertility

[f] age specific survivorship rate

[g] age specific fertility/2 (assuming 1:1 sex ratio)

Table 28. Daily maximum, minimum, and average temperatures at field insectary when fecundity, egg hatch, and longevity were investigated for females resulted from laboratory larvae under caged conditions on late vegetative soybean stage.

Date	Temperature (^{o}C)[a]		
	Minimum	Maximum	Average
8/10	21.7	35.0	28.3
8/11	22.8	32.2	27.5
8/12	23.3	34.4	28.9
8/13	24.4	35.5	30.0
8/14	23.3	34.0	28.7
8/15	23.5	36.0	29.8
8/16	24.0	33.2	28.6
8/17	24.0	35.5	29.7
8/18	23.0	36.1	29.7
8/19	22.5	34.4	28.4
8/20	21.7	35.3	28.5
8/21	25.0	34.0	29.5
8/22	-	-	-
8/23	23.2	32.2	27.7
8/24	23.5	33.0	28.2
8/25	22.8	34.5	28.7

[a] Recorded by hygrothermograph (Belfort® Model 1929-1A).

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BIOGRAPHICAL SKETCH

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Flavio Moscardi is married to Rosa Maria Lara Moscardi and has one son, Gustavo. He is a member of the Conselho Regional de Engenharia, Arquitetura e Agronomia do Estado de Sao Paulo, Sociedade Entomologica do Brasil, the Florida Entomologidal Society, the Entomological Society of America, and the International Organization for Biological Control.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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